THE INSTITUTION OF PRODUCTION ENGINEERS JOURNAL

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PRODUCTION ENGINEERS JOURNAL

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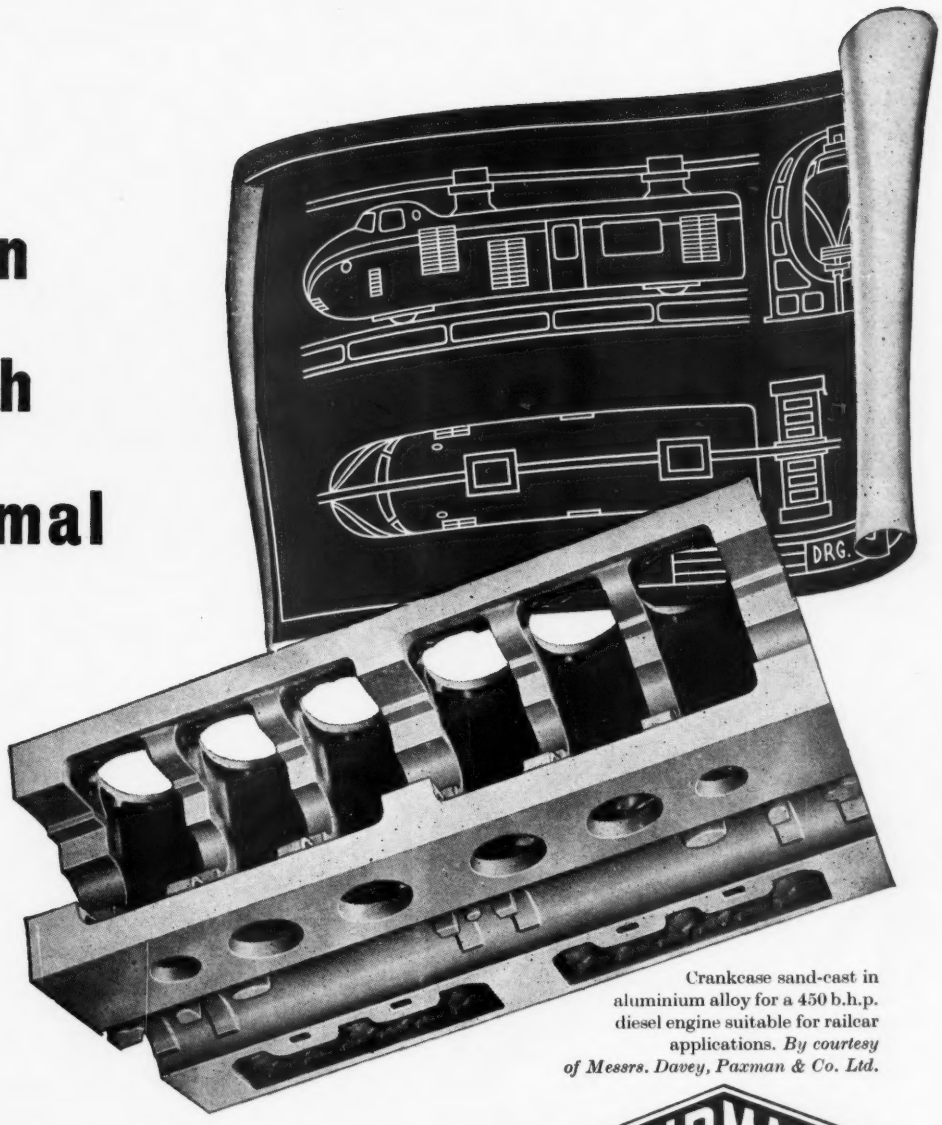

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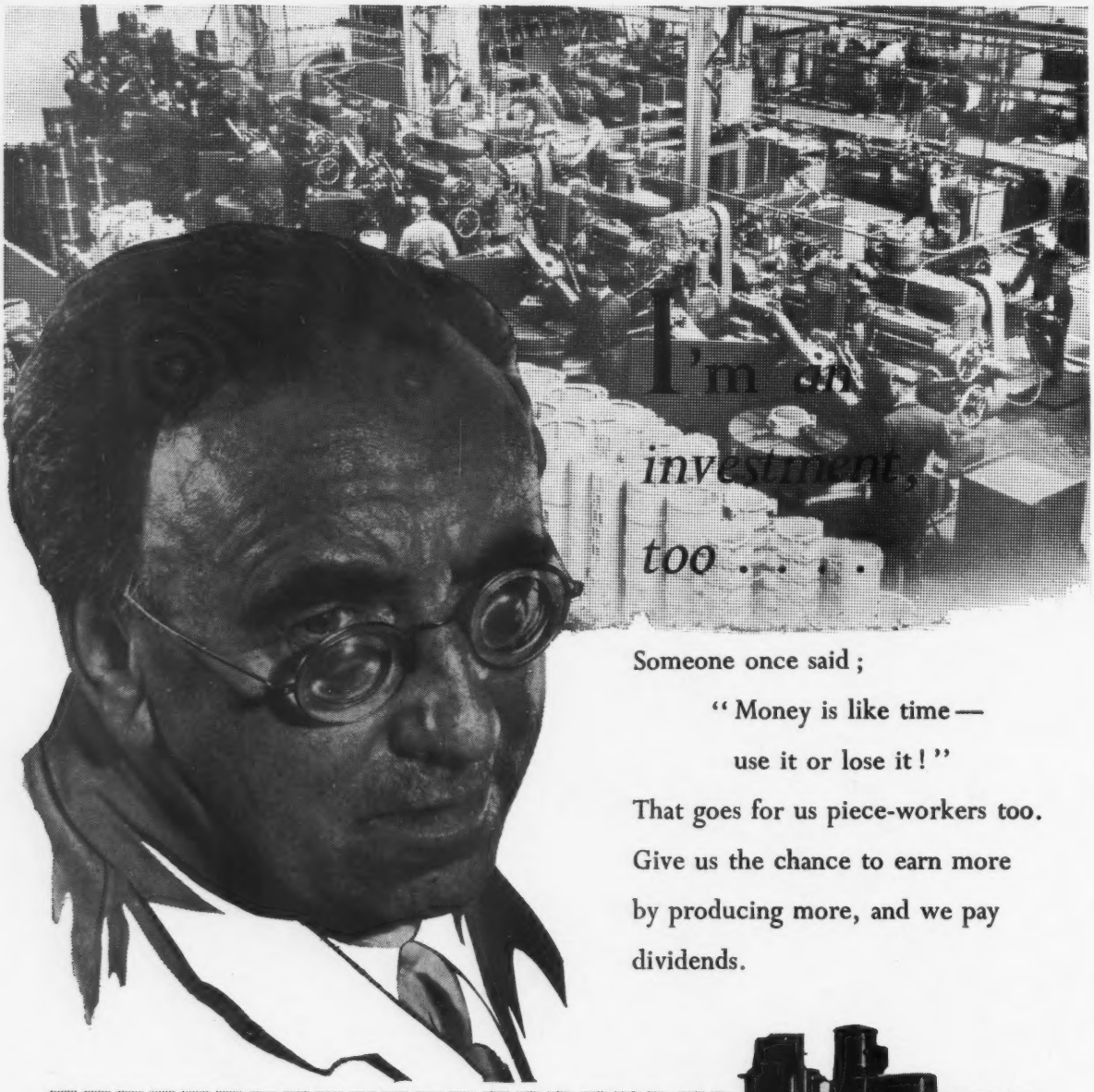

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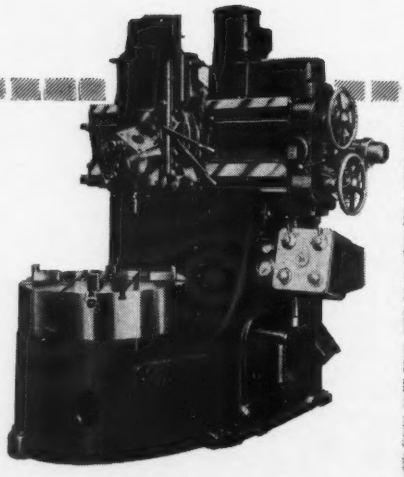

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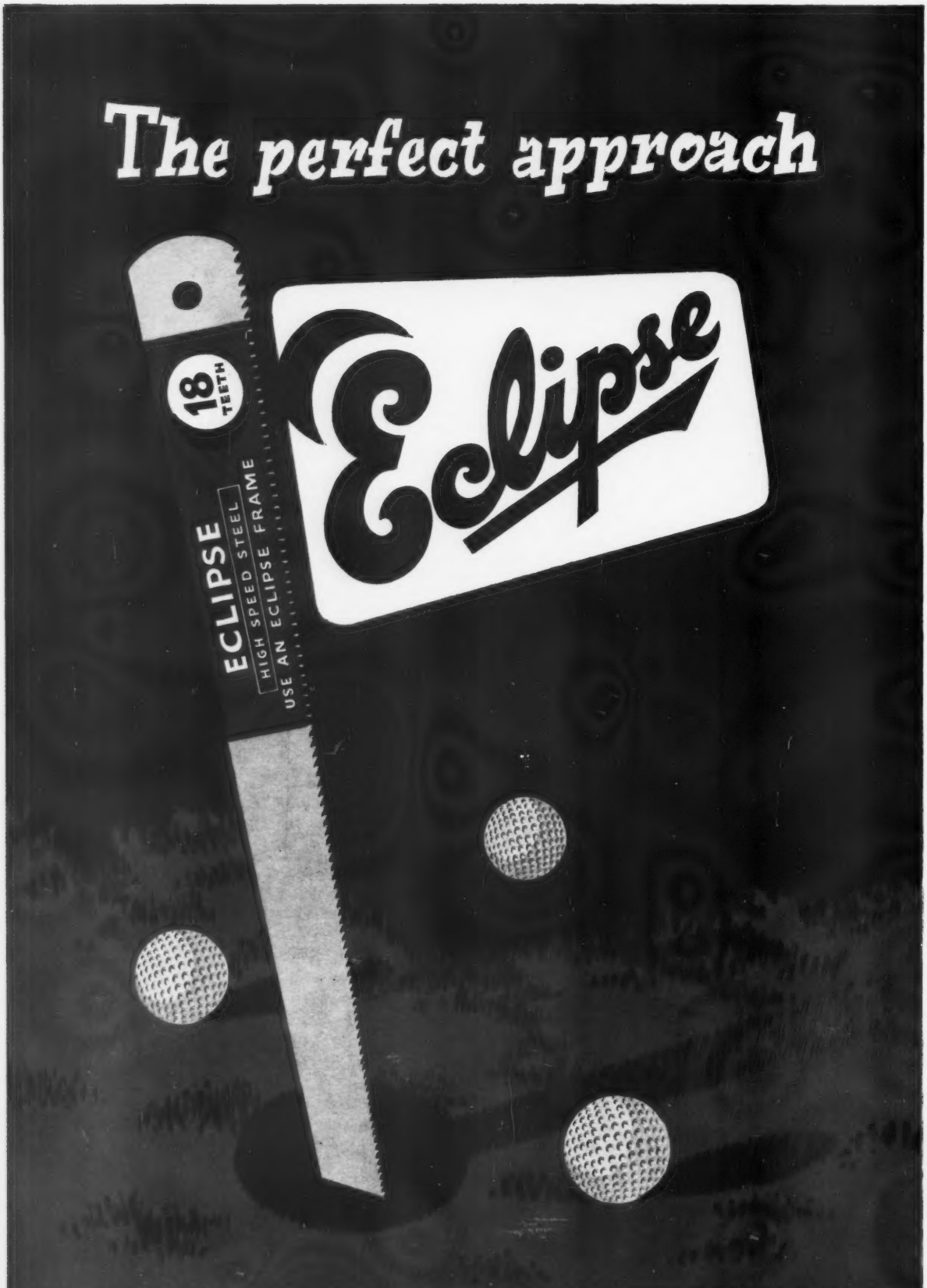

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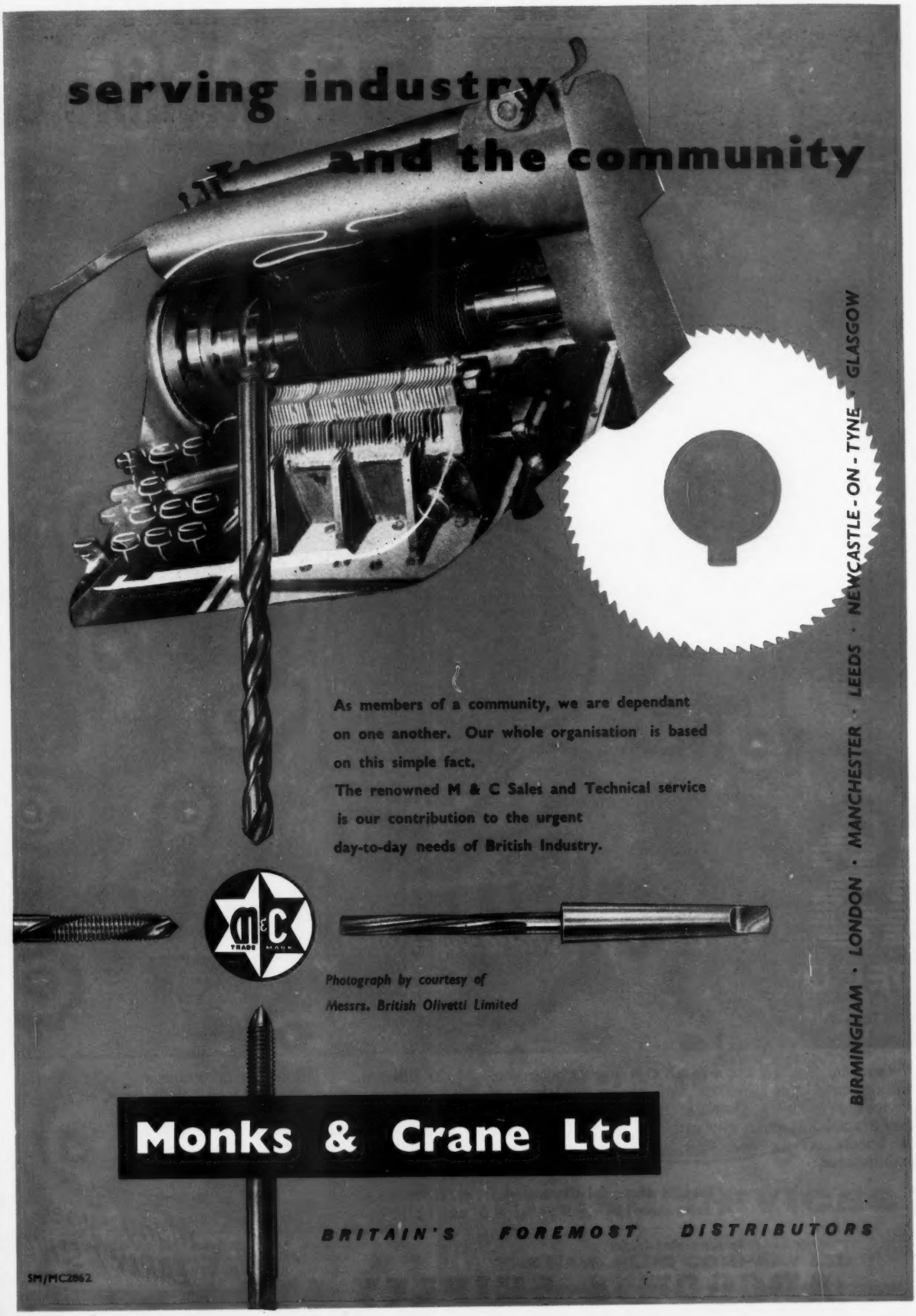
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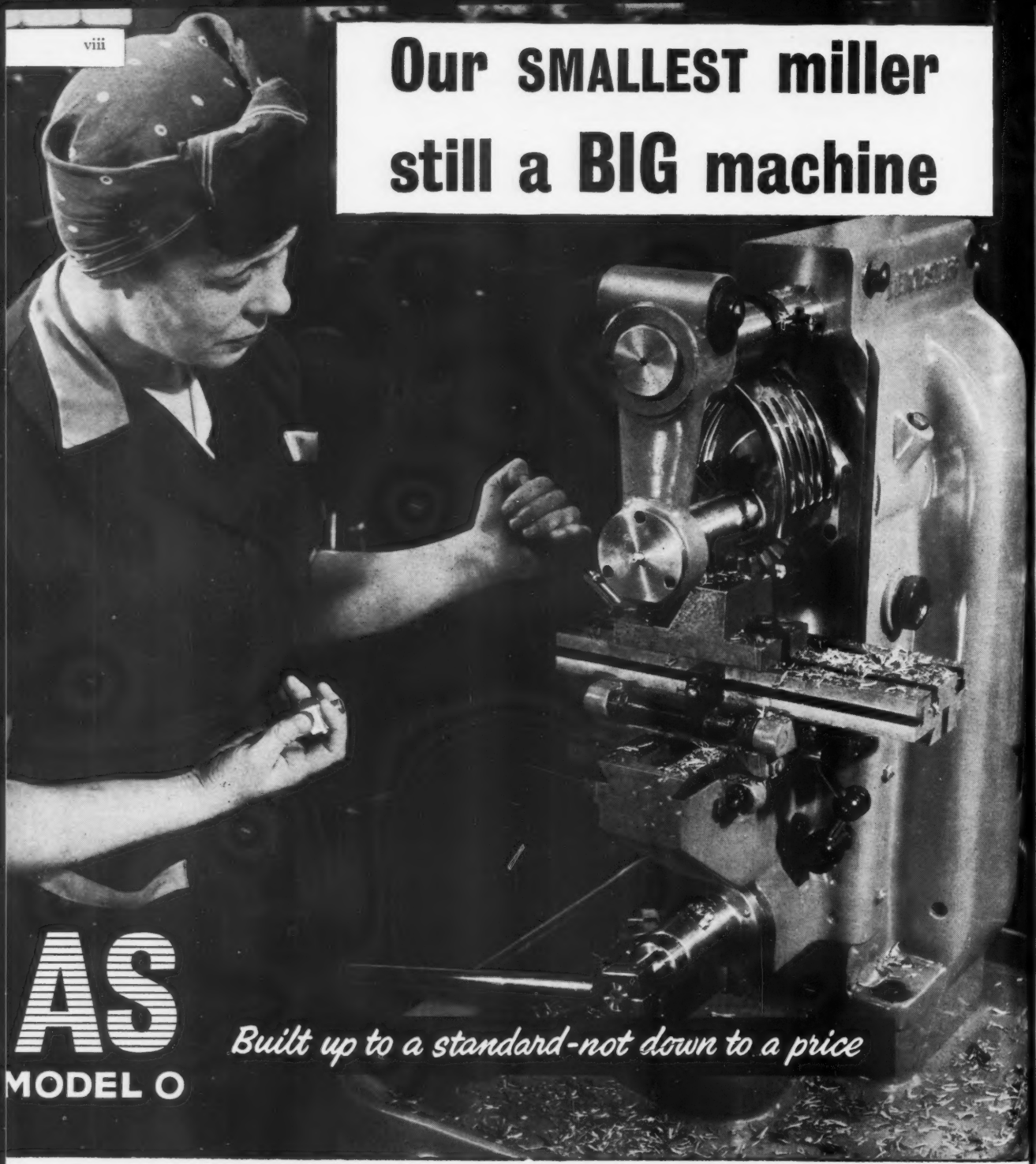

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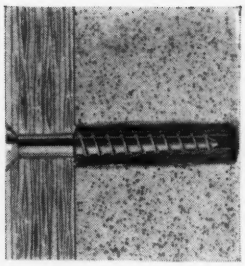

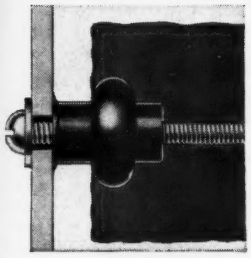

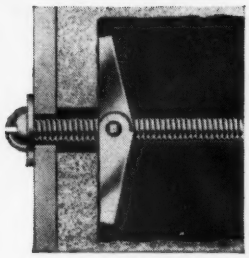

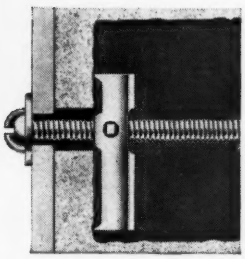

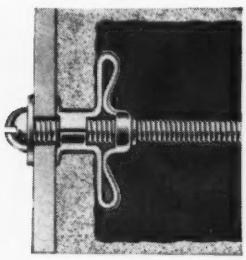

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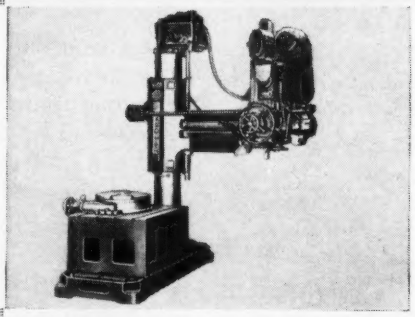

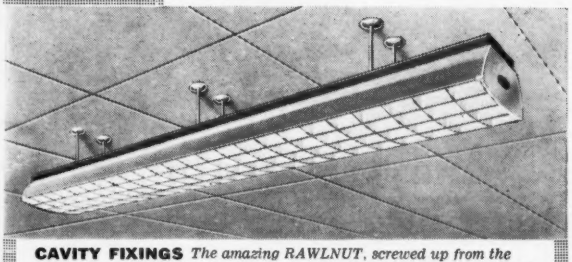

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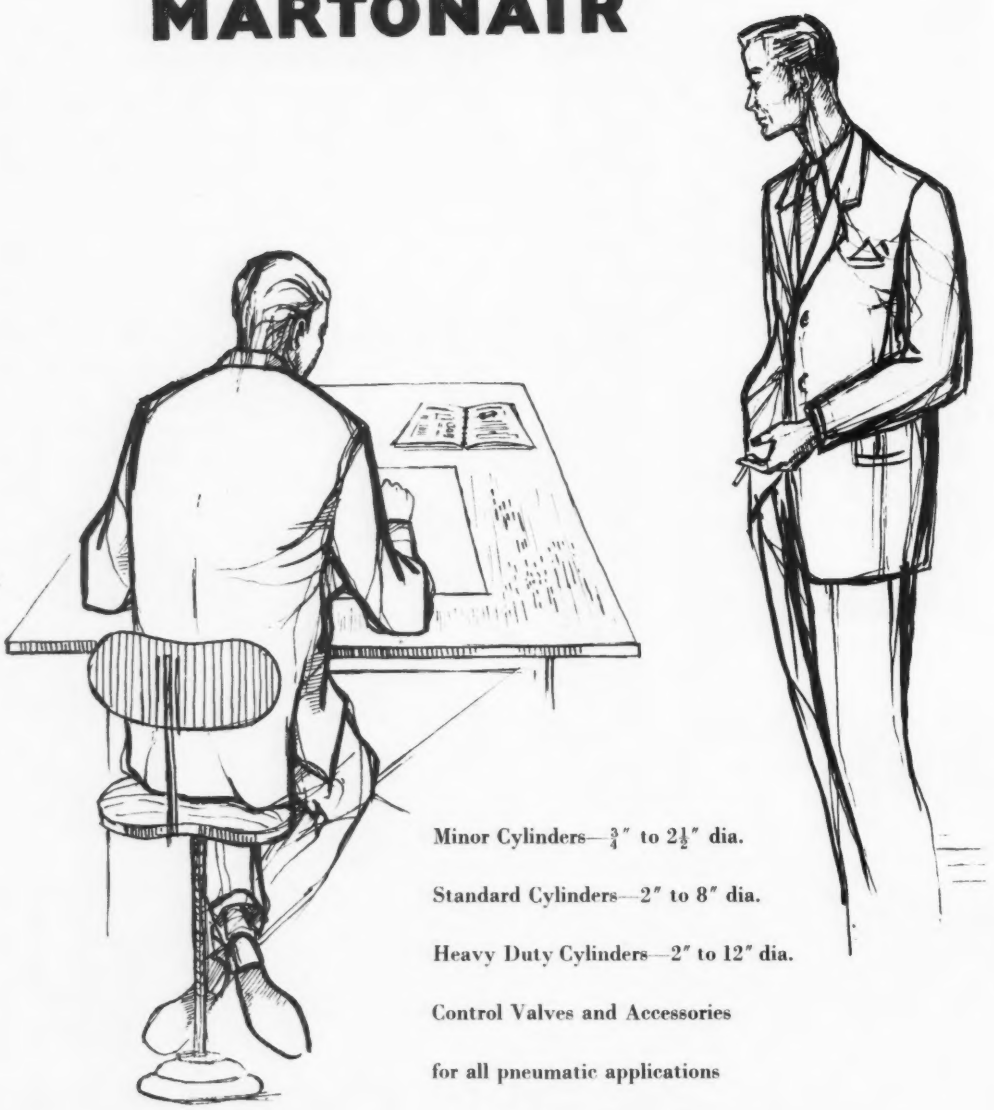

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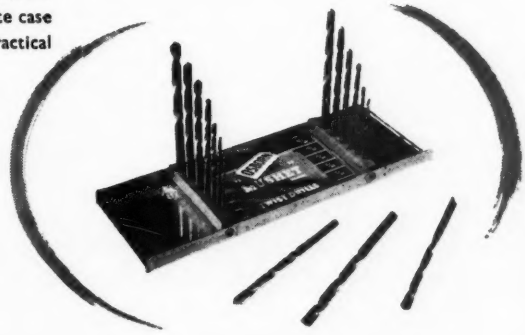

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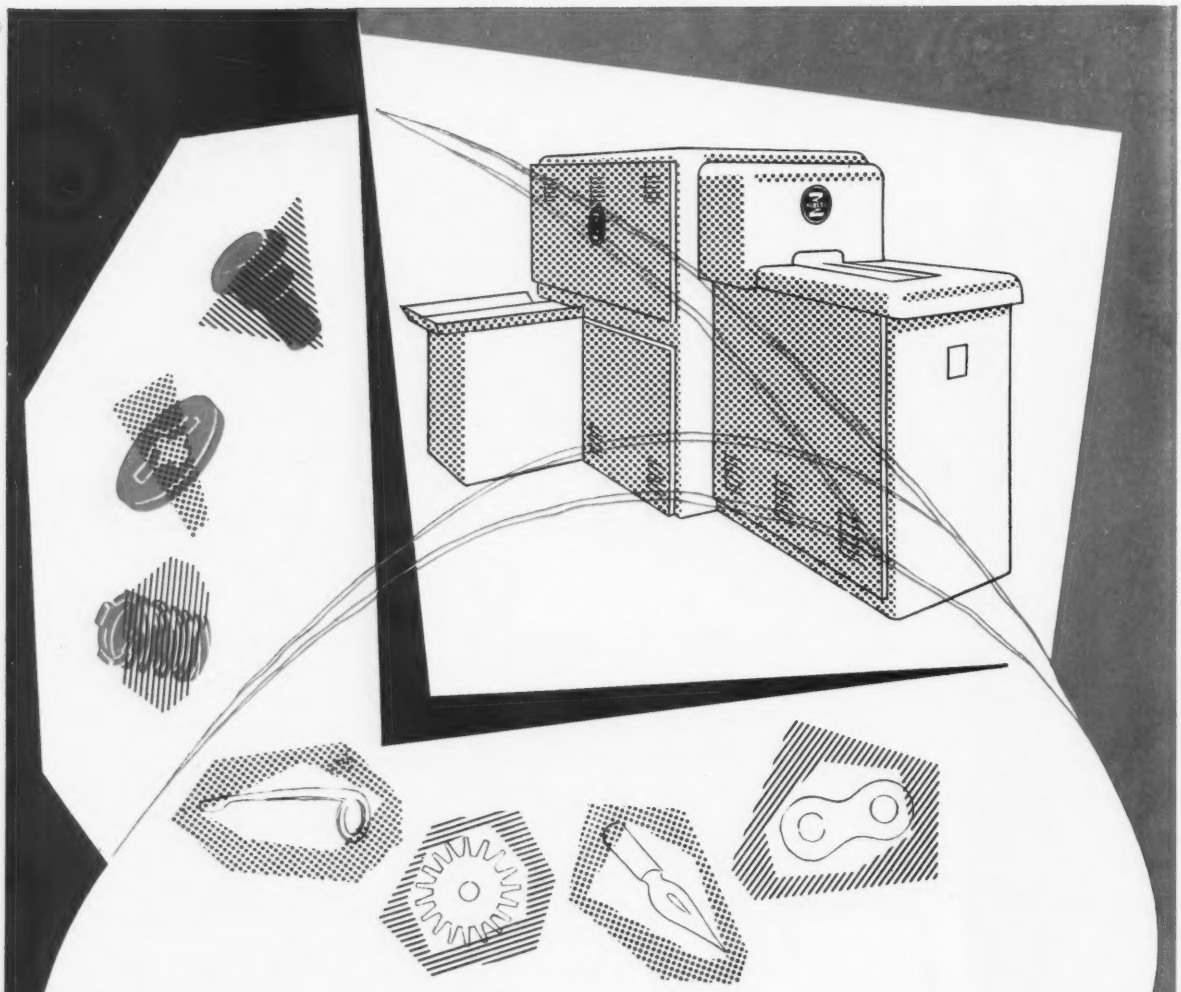

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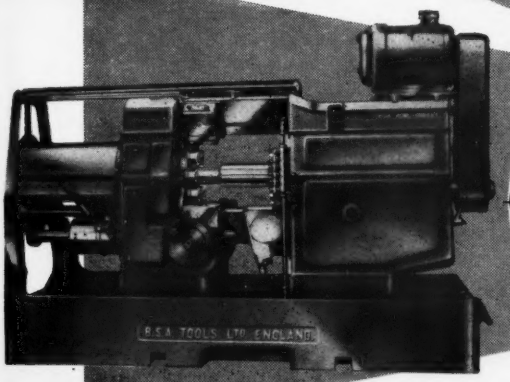

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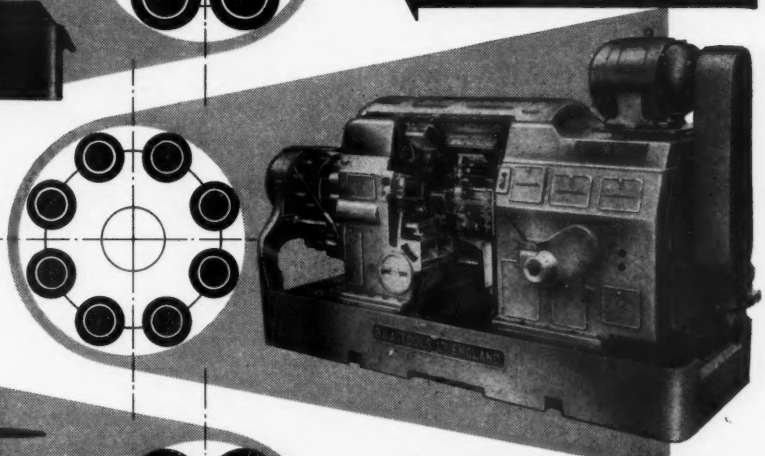
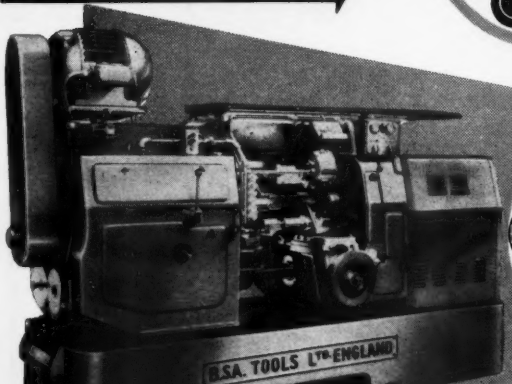
SIX SPINDLE

BAR
1⅝"
EIGHT SPINDLE





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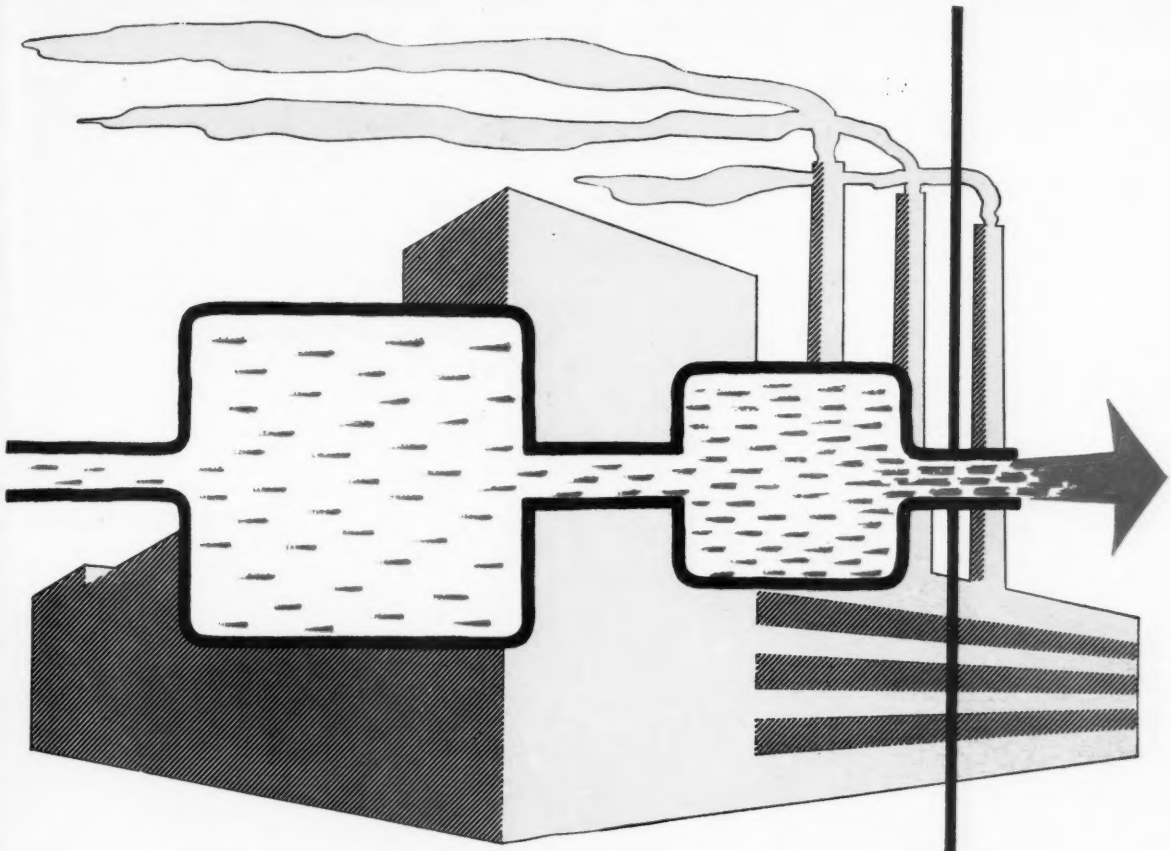

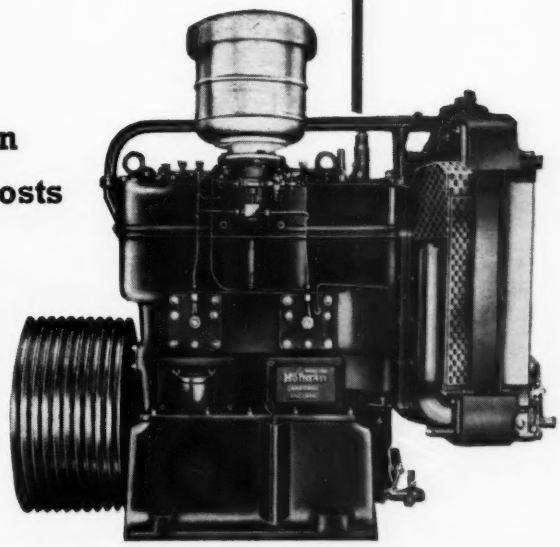

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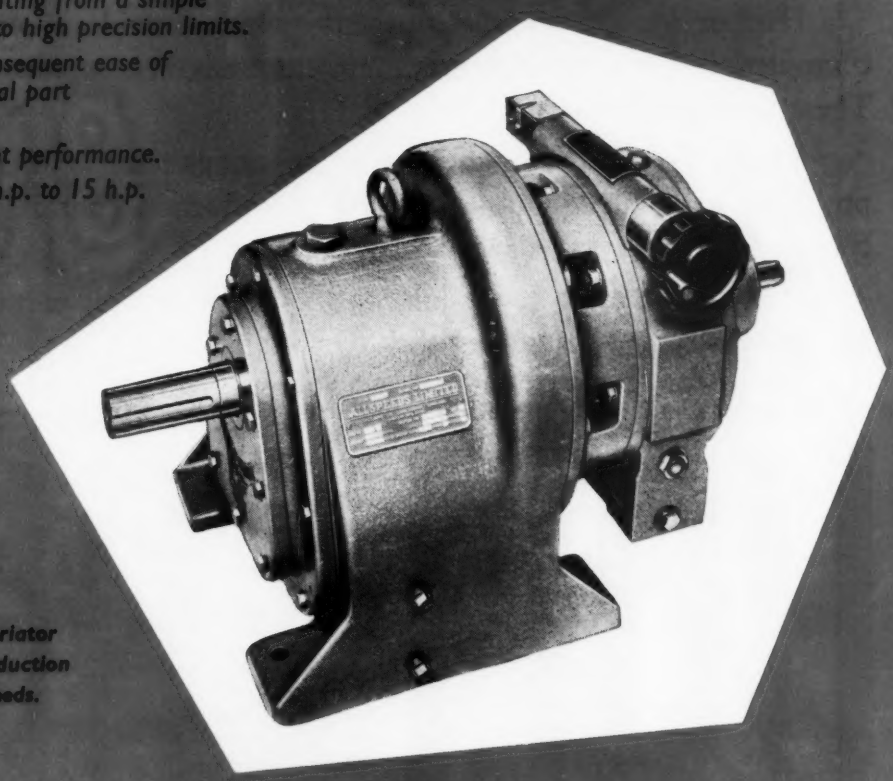

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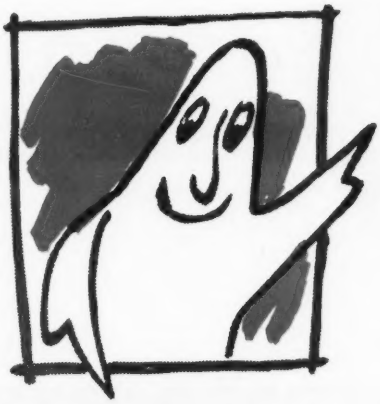
Ghost gets to work



Max Am gets down to it

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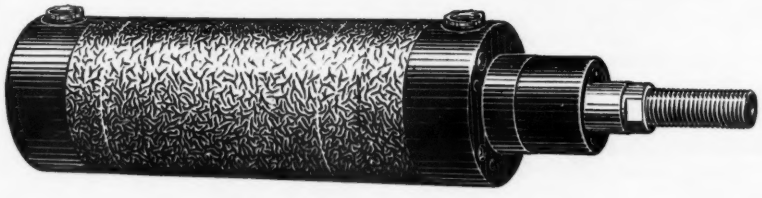

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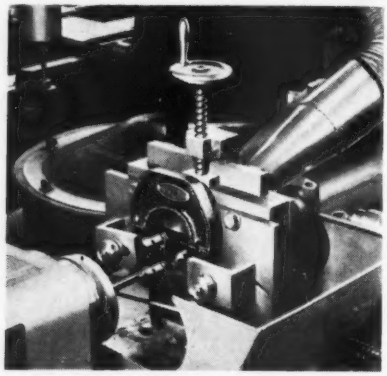

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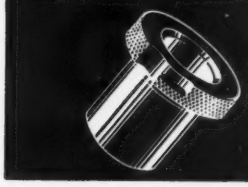

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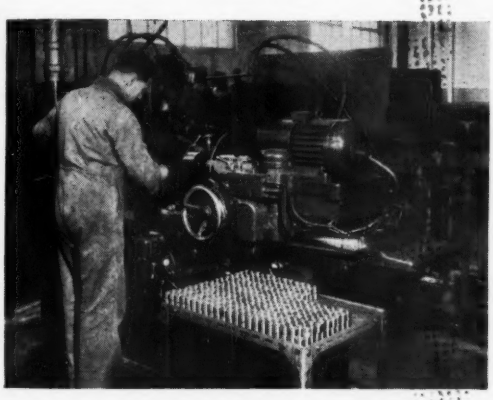

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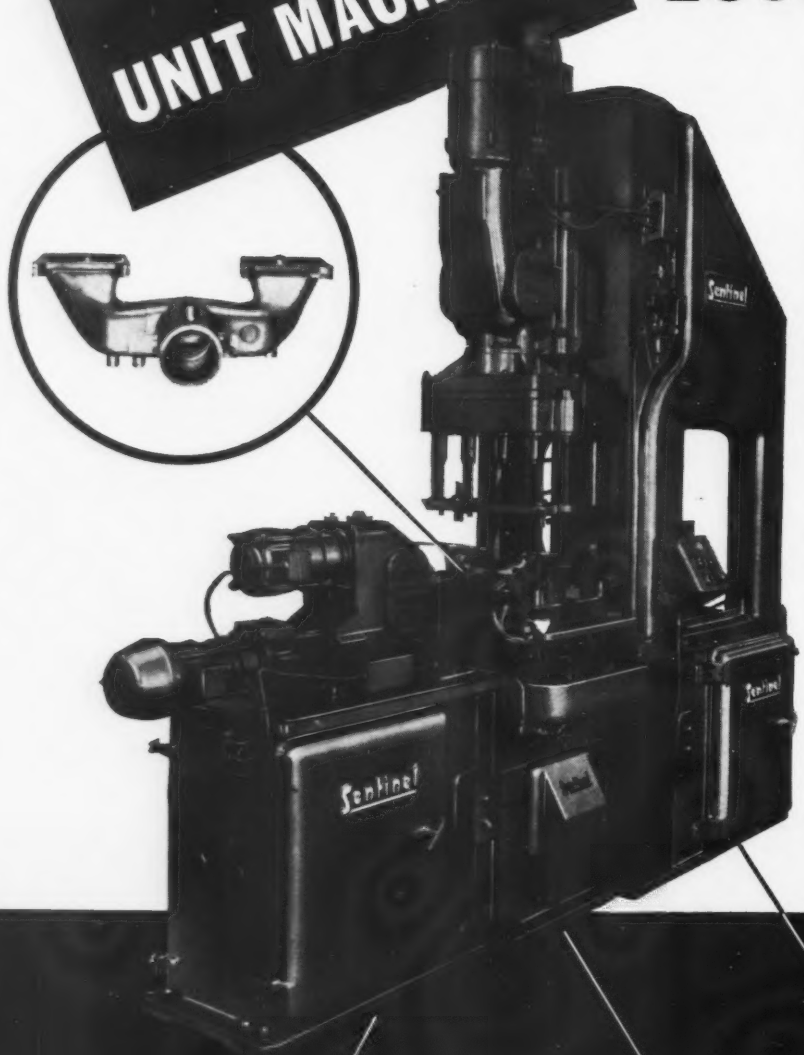

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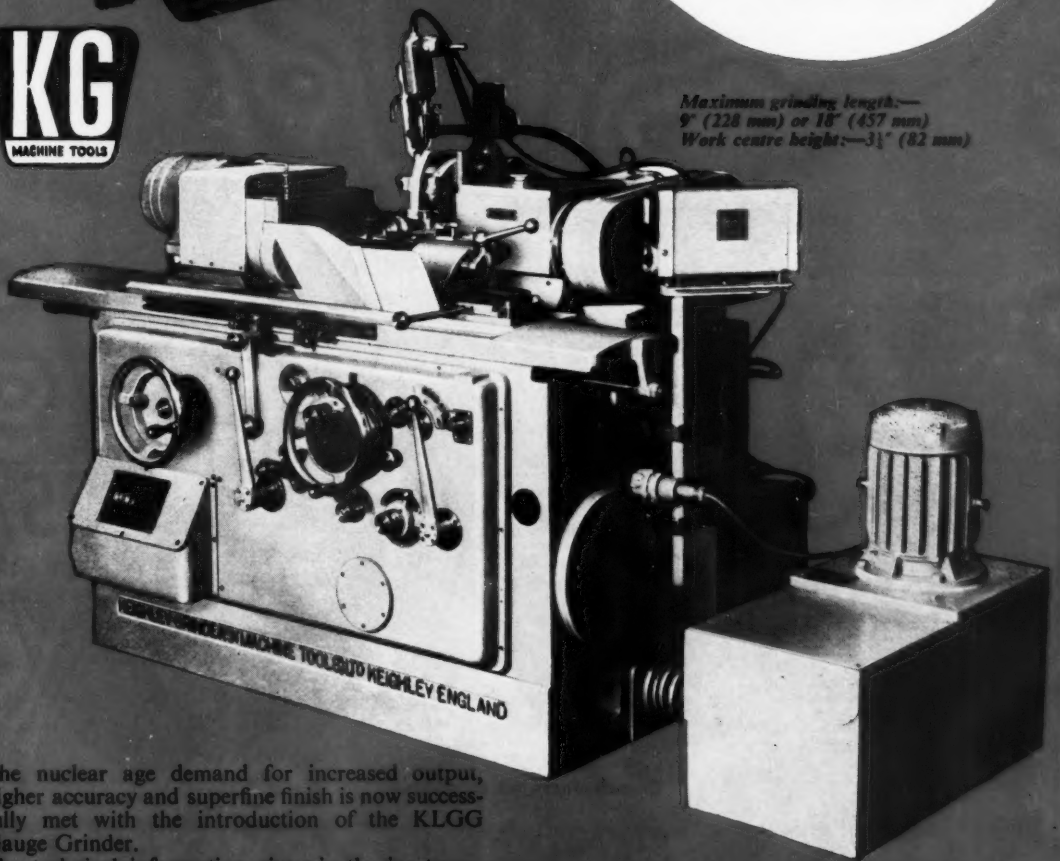

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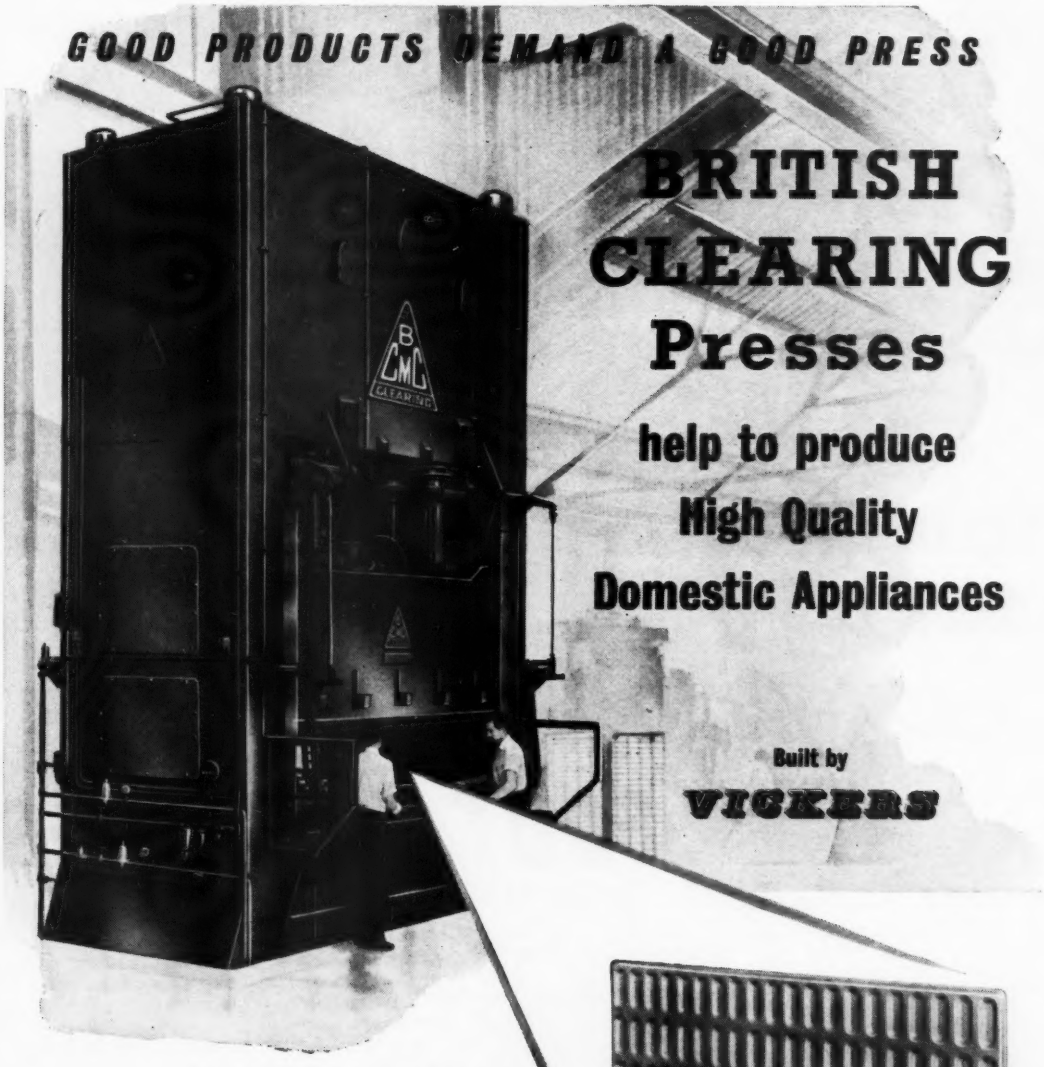

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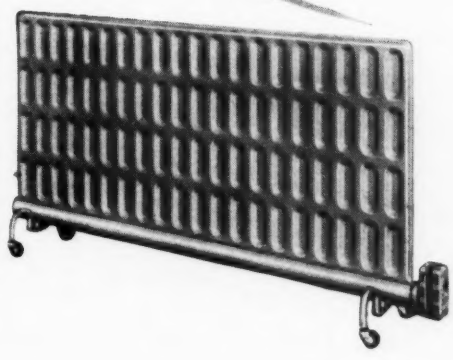

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Contact Arrangement	S.P.D.T.					TWO STAGE see insert below				TWO STAGE see insert below		250 volts A.C./D.C. maximum	
	D.P.D.T.												
Mechanical Latch		Two Stage Contact Arrangement						*	*	*	*		
Two-stage		Pedal Position				*	*			*	*		
Two-stage with Mech. Latch in 1st stage		Up		Half Down		Full Down							
Two-stage with Mech. Latch in 2nd stage													
Maintained Contact Ratchet type													
With Pedal Guard			*		*		*	*	*	*	*		*
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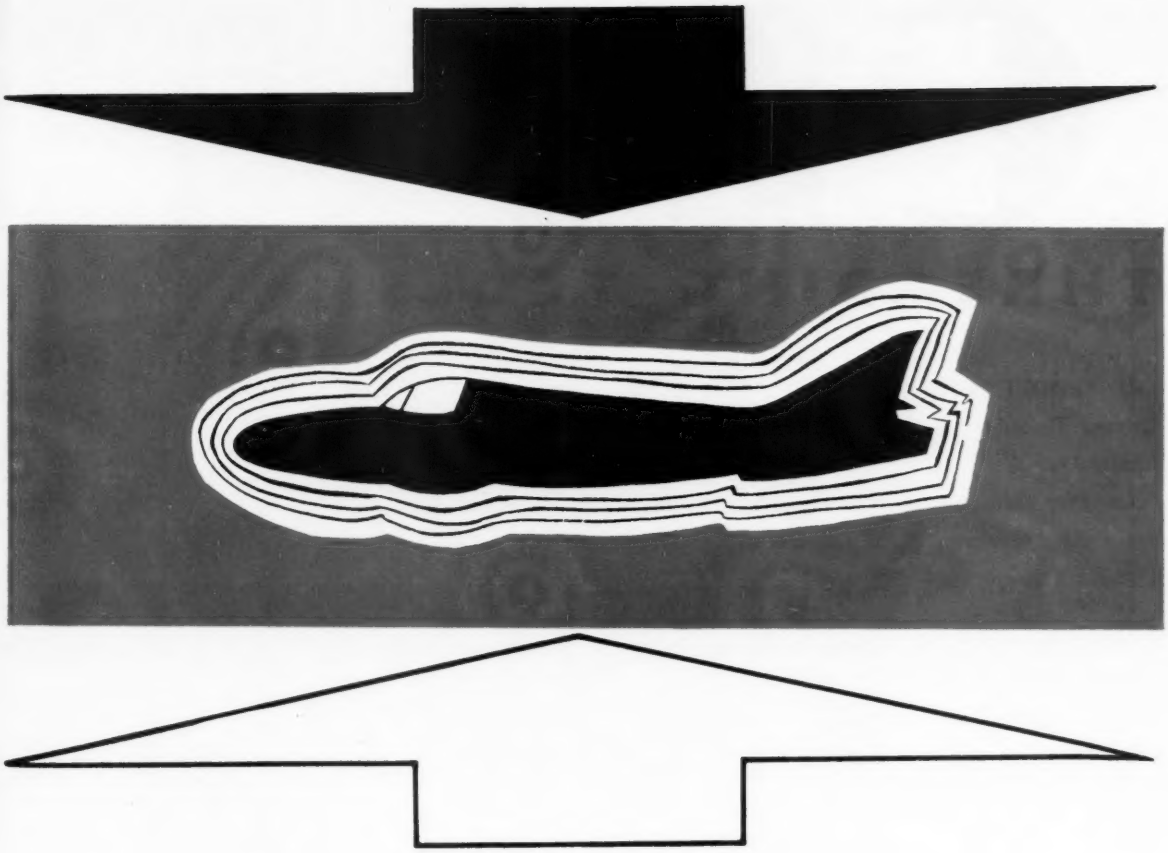

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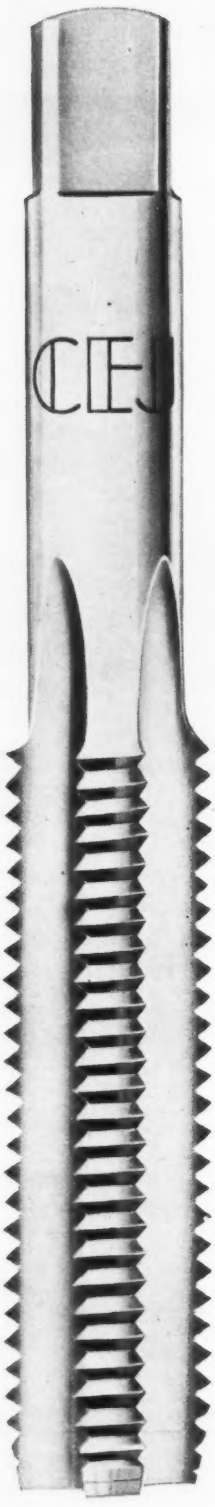

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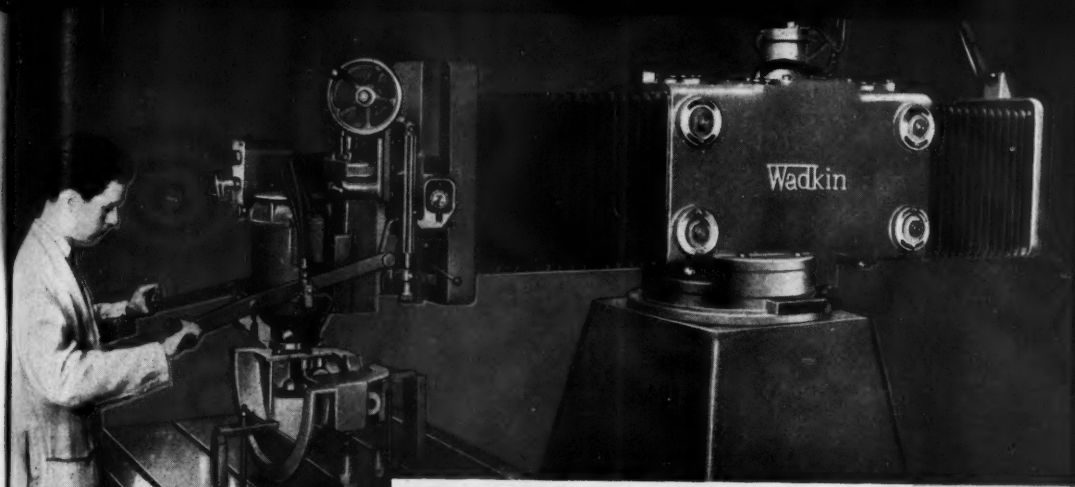

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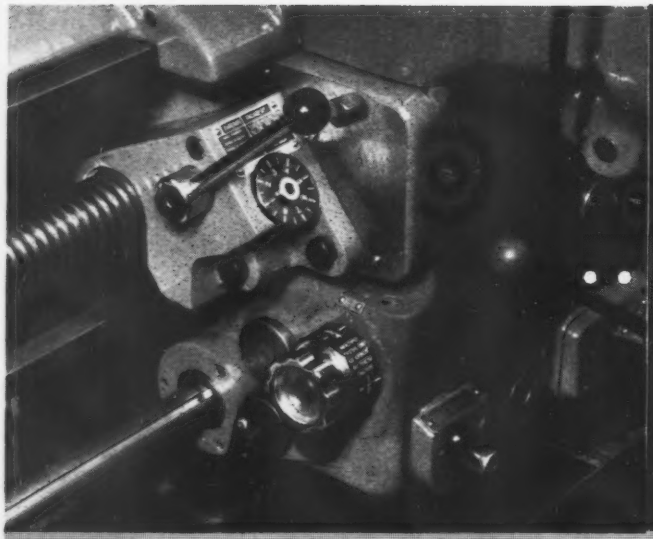

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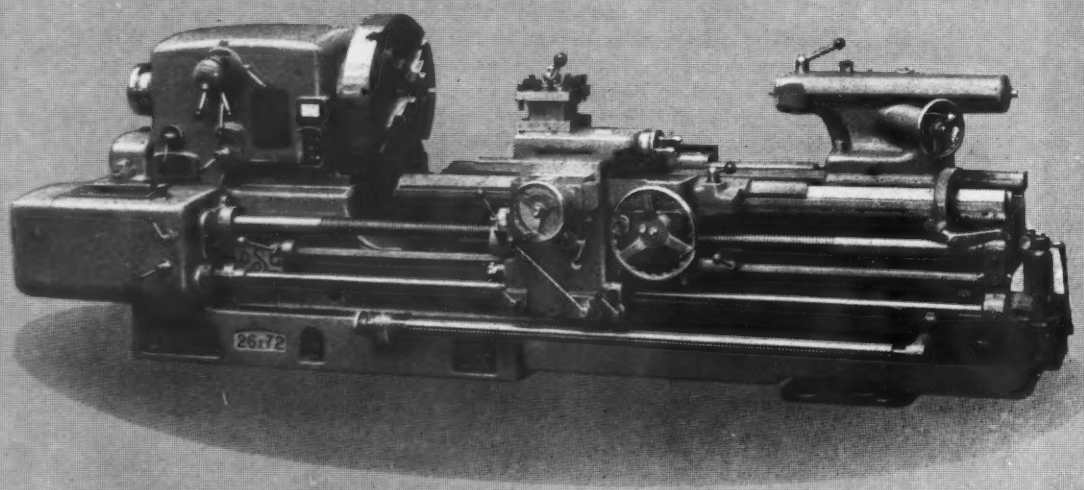

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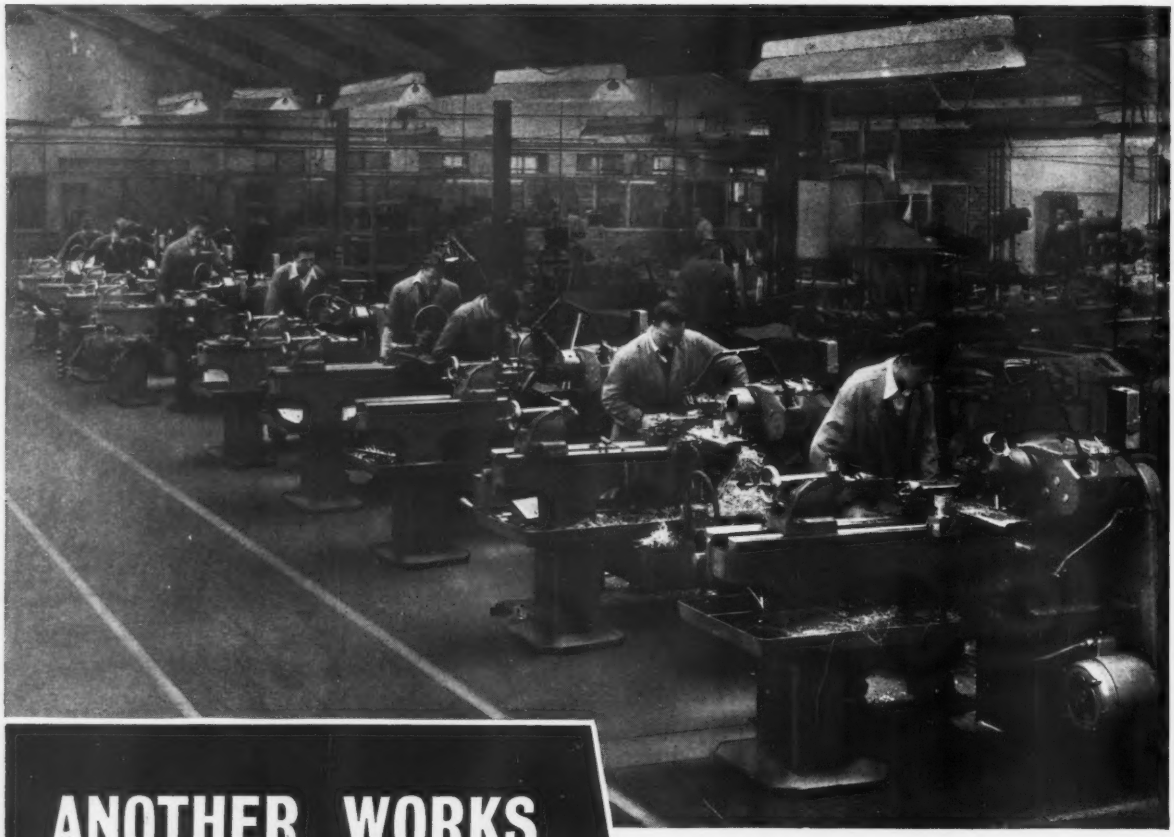

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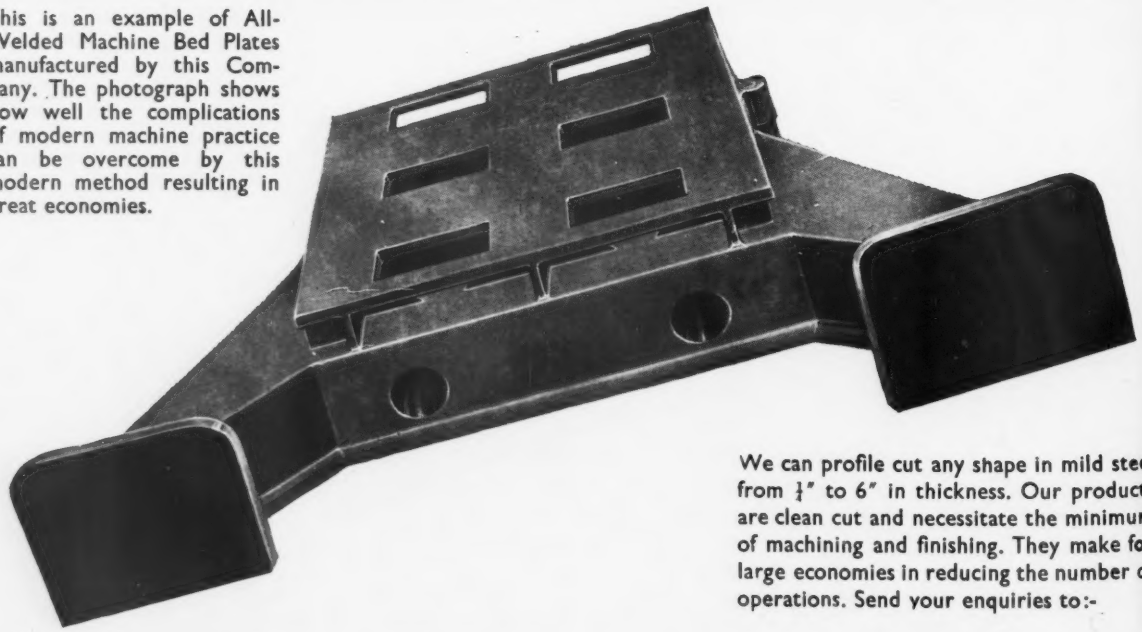

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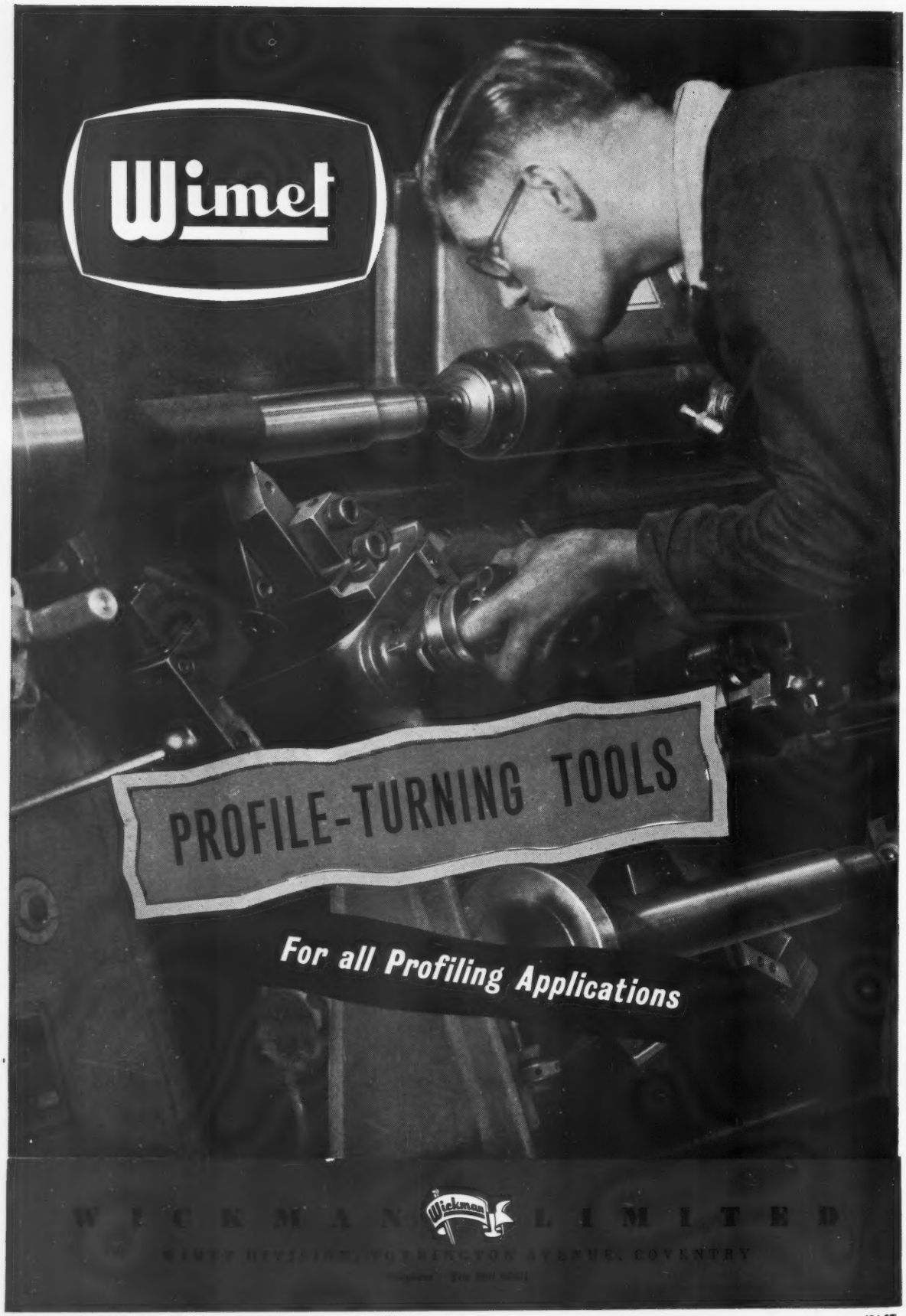
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The Institution of Production Engineers Journal
VOL. 37 No. 6 JUNE, 1958

The New Industrial Pattern of South Wales

by

A. J. Nicholas,

O.B.E., M.I E.E., Assoc.M.C.T.

Mr. Nicholas is Managing Director of South Wales Switchgear Limited, and the Immediate Past President of the Industrial Association of Wales and Monmouthshire.

The comments published here are extracted from an address given to the Cardiff Section of The Institution of Production Engineers on 24th January, 1958.

TO consider the industrial pattern of South Wales it is necessary to have a little knowledge of the historical background of industry. The mechanical, electrical, chemical and commodity industries created in the London, Midland, Manchester and Northern areas of Britain started from small beginnings. The textile industry of Lancashire gave rise to the manufacture of machinery for the mills and this engineering activity extended outside the textile field and formed the large mechanical engineering organisation of Manchester and district; in the Midlands, known as the hardware shop of Britain, mechanical engineering, too, became a flourishing industry; the manufacture of electrical plant is fundamentally mechanical and it was natural that electrical engineering should find roots in the London, Midland and Northern areas, to develop into the large concerns there today.

It is easy, now, to say that Wales, too, should have developed manufacturing industries, but the basic industries of coal and steel were those on which Wales relied. Capital plant machinery was not used to any considerable extent and by the time that mechanisation had been developed, engineering had already been established in large industrial areas of Britain. Thus the basic industries of Wales were equipped with machinery manufactured in England, and engineering was not developed in Wales alongside the industries it should have served.

These basic industries were the first to be affected by two major economic depressions between the World Wars and Wales suffered acutely; in the valley towns, just before the last War (1936 - 1937), unemployment amongst adult male labour was 40% to 50%.

There was, however, one break in the pattern of Welsh industry of the pre-war period; the growth of Hitler's power and the resulting purges in Germany and in other countries caused refugees to find homes and livelihood in Britain. Trading estates were developed and a number of refugee industries were established at Treforest and in the Welsh valleys.

war-time changes

The War, of course, changed events. There was no longer adequate labour in the industrial areas across the border to deal with a mechanised war and, coupled with the need for dispersal of industry as a protection against enemy attack, large factories were established in the Welsh valleys. For the first time in history, Wales became a manufacturing unit as well as a coal and steel supplier. This production of war materials converted the Welsh youth to factory practice and the seeds were sown for what was to happen in the post-war years.

In the past, succeeding Governments had done little to change the pattern of Welsh industry; now the Government was concerned with what would happen when the War ended. A number of factories were erected throughout those zones where unemployment was likely to be in post-war years. These factories were allocated to industries engaged in war work but, equally important, they had a post-war programme which would enable them to carry on when the War ended. This was a beginning, but a much more ambitious solution to Wales' industrial development had to be found.

post-war development

The post-war period had two factors of advantage; a seller's market existed both at home and abroad, and there was direction of industry by the Government for British firms wishing to expand. New factories were located in development areas of which South Wales was one of the most prominent. The pattern of Welsh industry, however, was largely determined by the class of labour available; war-time experience had been in work of a repetitive character, for which labour could quickly be adapted for production without long terms of technical training or long apprenticeships.

The four great sections of industry are: the basic industries, represented in Wales by coal and steel; the large process plant industries, such as the chemical, oil and textile; the mass production industries of commodity products, which include the everyday requirements associated with our standard of living, such as electrical appliances, hardware, plastics, etc.; and capital plant manufacture. Wales is well represented in the first three classes and indeed stands at as high a level in these as any other part of Britain, but whilst these three classes of industry employ large numbers of unskilled and semi-skilled operatives, they need only a few skilled or technically-trained men for maintenance, research and management.

The fourth industry requires the skill of technologist and craftsman in design and production. There is employed in it a large labour force involved in engineering, drawing office work, administration and testing, and the industry can absorb better class labour as it becomes available from grammar schools, technical colleges and other educational organisations.

Wales, then, needs a better balance of its industries — the development of capital plant manufacture — for it should not be necessary for a young man wishing to take up a professional career to leave his "native heath". Further, we are living in an age when the plant and tool equipment in a factory play a greater part in efficiency than the manual labour, and this tendency is growing. The days have gone when the craftsman on the shop floor produced the commodity article. Automation and mechanisation have changed this. Our competitive power in export markets and our ability to raise the standard of living at home depend upon the efficiency of capital plant in all its wide diversity.

the present position

In the first inrush of new industries in the post-war years, there were many taking advantage of the demand for goods. Some of these have not been able to survive in a competitive market. We may sympathise, but Wales needs virile and efficient industry.

There is another class of industry with headquarters located in the large industrial areas of Britain, together with manufacturing facilities, design staffs, etc., and using factories in Wales as production units only. Many of these are making big contributions to Wales' economy, but if business were to recede these "branch" factories could be closed, leaving the headquarters organisation to cater for the reduced demand.

An aspect of the Welsh economy which is different from elsewhere is that a high percentage of the industries are located in Government factories and, in these days of "credit squeeze", a complete stop to expansion can be brought about by Government legislation.

future policy

The task ahead — that of bringing about a new technical age — is immense.

The days are gone when any business was welcome, and more analytical planning for the future of Wales is necessary. The Government has now had sufficient time since the immediate post-war years to satisfy itself about the class of industry which is capable of development and to give the support that is needed for expansion. In this, the Government should consider first those industries which are already established and have proved their worth. One possible danger to be avoided is the overcrowding of industry in those areas where labour is not available.

To produce more technical men in Wales, managements must carry the burden of more apprentices and their training; education authorities must obtain the best class of science and mathematics teachers, and must integrate themselves with the problems and growth of industry in their areas; and the trades unions, and the workmen, must help in the training of apprentices associated with them.

Current Experimental Work with Sintered Oxide as a Cutting Tool

by **H. Eckersley, M.I.Mech.E., M.I.Prod.E.**

and R. N. Cook, A.M.I.Mech.E, M.I.Prod.E.

A Paper presented to the Midlands Region of The Institution of Production Engineers, in Coventry, on 24th March, 1958

THE purpose of this Paper is to review the wide range of current experimental work being conducted in various countries using sintered oxide as a cutting tool.

In order to place sintered oxide in its relative position as a tool material, it is desirable to examine those other materials which are also available as a choice for such duty. At the same time we must bear in mind the ideal properties of any cutting material, which are high hardness, chemical inertness, high thermal conductivity, high compressive strength at elevated temperature and low thermal expansion.

Materials that merit consideration are provided by the carbides, oxides and borides of those metals in the 4th, 5th and 6th Groups of the Periodic Table of Elements.

Some of these materials, presented in descending order of hardness from the diamond, are :-

the diamond;	silicon carbide;
boron carbide;	aluminium oxide;
titanium boride;	titanium carbide;
aluminium boride;	tungsten carbide.

Attempts have been made to produce all these materials by various methods, but the basic problem is to produce an alloy which will give the range of requirements for a cutting material where hardness alone is not the sole criterion. Aluminium oxide at present seems to offer some prospect of achieving this aim.

The experimental use of tools made from a material that is basically aluminium oxide goes back to the early 1930's. It was the last War which stimulated further research and development into the possibilities of this tool material, since manufacture of tungsten carbides employed strategic raw materials which might have become impossible to obtain. The Wickman Group carried out a great deal of work in this direction in the War years and subsequently obtained patent cover.

The raw materials from which carbides are made did not become seriously short during the War and the urgency for further development work on oxide tooling disappeared. After the War, the raw material supply for carbide manufacture became satisfactory

in Germany and Russia, which diminished their interest in oxides at that time.

Interest was re-stimulated at the Chicago Fair in 1954. Here, demonstrations with such tools were made, mainly as a machine tool sales attraction, and were therefore accorded considerable publicity. Sintered oxides have, therefore, developed rapidly and are now very different from the results of the earlier efforts which were made towards their construction and manufacture.

Collectively, materials which are basically aluminium oxide have acquired many different names and in our opinion the terminology has become unnecessarily involved. The definition "ceramic" or "keramic" is too wide to define accurately the material produced specifically for use as a cutting tool, and neither is the term "cemented oxide" accurately descriptive of the material. In future we intend to refer to such material as "sintered oxide", in the same way as we refer to "sintered hard metals".

The first reports from America concerning sintered oxides claimed cutting speeds from 3 to 10 times higher than those normally associated with sintered carbides. Whilst such speeds remain a target for the future, the Americans have recognised that to increase cutting speeds without increasing metal removal rates is pointless, since most of the current designs of machine tools can already be fully exploited using sintered carbides.

Just as the technique of applying tungsten carbide is the result of 30 years' continuous development and experience, so it is futile to expect application techniques for oxides to be understood before there has been a very close investigation of the field of exploitation.

At present the knowledge of application techniques with oxides is limited by factors which include :-

1. Present reservicing techniques are not sufficiently developed.
2. The material is brittle and restricted in its load carrying capacity.
3. Direct attachment to steel or other shanks is not yet generally reliable.
4. This apparent necessity for clamping restricts to some extent the general flexibility of the geometry.
5. The upper limit of attainable cutting speeds can only be established on machine tools specifically designed for the purpose.

Also, the success of oxides will be dependent upon their being developed to satisfy any or all of the following requirements :-

1. The establishment of a structure suitable for the loads to be imposed at high speeds.
2. The ability to accept intermittent or shock loading resulting from interruptions in the surface being machined, variation in the depth of cut and in the structure and characteristics of the material being machined.
3. The provision of several grades of oxide to satisfy optimum metal removal rates and standards of finish.

The investigations now being carried out in most industrialised countries are directed towards obtaining performances with oxides in advance of those at present possible with carbides. Machine tool makers, in particular, will be interested in discovering those influences which will affect business and open up new markets. At the same time, it is also reasonable to expect enhanced performances from carbides when machine tools are available that have been designed for higher speeds under conditions of increased rigidity and power. There is still much scope for broadening the application of carbides, given advancement in machine tool design and, even more important, a close appreciation of tooling requirements by the machine designer, factors which, we regret to say, are too often ignored at the present time.

THE AUTHORS

Mr. Eckersley (left) *is a Director of Wickman Limited.*

Mr. Cook (right) *is Research and Development Manager of Wickman Limited (Wimet Division).*

Tool Material	Hardness V.P.N. Room Temp.	600° C.	800° C.	Transverse Rupture Strength lbs/ins.	Young's Modulus lbs/ins.	Coeff. of Thermal Conductivity C.G.S. Units	Coeff. of Thermal Expansion per °C.
Carbon steel	700–900	200	100		$30x10^6$	0·14	$14·7\ x10^{-6}$
High Speed Steel	650–800	600–700	200	$400x10^3$	$32·5x10^6$	0·061	$12·8\ x10^{-6}$
Cast cobalt based alloy	600			$150–180\ x10^3$	$30\ x10^6$		$14·5–16·9x10^{-6}$
Tungsten carbide cobalt	1200–1800	1000–1200	700–900	$150–350\ x10^3$	$75–88x10^6$	0·19	$4·8–6·0\ x10^{-6}$
Tungsten-titanium carbide cobalt	1200–1800	1100–1250	900–1000	$120–250\ x10^3$	$70–75x10^6$	0·09–0·15	$5·0–7·0\ x10^{-6}$
Sintered Oxide	1500–1800			$35–90\ x10^3$	$50\ x10^6$	0·056	$7\ x10^{-6}$

Fig. 1.

The only purpose in searching at all for an improved cutting material is to increase productivity. The object of our experiments is to develop a reliable cutting material which will achieve the highest possible economic metal removal rate commensurate with the limitation imposed by the rate of machine tool development.

It is for this reason that these experiments have at all times employed oxides and carbides side by side. It is intended that subsequent work will establish the best cutting material, be it oxide, carbide, or other products, to meet the needs of particular classes of work.

At this stage, it is useful to refer to the relative properties of those cutting materials in general use today, compared with those of sintered oxide (Fig. 1)[1].

We should also examine the types of wear and deterioration experienced in cutting tools and the physical properties demanded from the cutting tool in order to minimise or overcome them (Fig. 2) [1].

Type of wear or deterioration.	Properties required in tool material
Flank wear	High hardness. Chemical inertness.
Cratering	Chemical inertness.
Build up	Chemical inertness.
Deformation	High compressive strength at high temperatures Chemical inertness. High thermal conductivity.
Fracture due to mechanical stress	Toughness.
Cracking due to thermal stresses.	High thermal conductivity. Low thermal expansion High tensile strength. Low Young's Modulus.

Fig. 2.

current world progress

To atempt an analysis of progress made in America, Europe and Russia is not easy. There has been much information published and many conflicting reports on the performance of oxides, to the point of near confusion. It is hoped that the notes which follow may assist clarification.

(a) *American*

Some of the claims made by our American contemporaries for sintered oxides appear to us to be optimistic. We have, however, extracted some information from the more reliable sources known to us.

An examination of the manufacturers of oxide in the U.S.A. brings to light the interesting fact that the majority have no direct interest in carbide manufacture. Of the major hard metal manufacturers, only Carboloy and Vascalloy Ramet have so far introduced oxide grades (Fig. 3). It can be expected that the background and experience gained in

Product Name	Maker	Colour	Type
ALUNDUM	Norton Company	Grey-Black	Clamped
ALSIMAG 614	America Lava Corp'n.	White	Clamped
* CARBOLOY	Metallurgical Prod. Dept., G.E.C.	Black	Clamped
CERALOX	Kearfutt		
DIAMONITE	U.S. Ceramic Tyle Co.	Pink	Clamped
KERAMIK	Raybestos Manhattan Inc.	White	Bonded
* SERAMET	Vascolloy-Ramet Corp'n.	Black	Clamped
STUPALOX	Stupakoff Division Carborundum Company	Grey	Clamped

*Manufacturers of Carbide

Fig. 3.

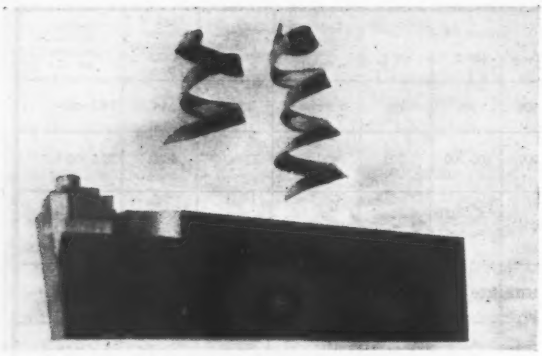


Fig. 4.

industry by hard metal manufacturers is of considerable advantage to them when considering and making recommendations for oxides.

We propose to consider four sources of information from the U.S.A. :-

1. The Carboloy Department of the General Electric Company.
2. Warner & Swasey, Cleveland.
3. Massachusetts Institute of Technology.
4. Watertown Arsenal.

1. *Carboloy*

Carboloy refer to their product as cemented oxide and have given it the designation "030". In establishing optimum tool geometry, Carboloy have reached conclusions similar to our own. They appear to have accepted, as we have, a slight departure from the optimum in order to be able to use tool holders already established for clamped tungsten carbide tips.

They also consider that present-day machine tools do not have high enough speeds to utilise fully their oxide tips, so that the tendency is for their use on harder steels up to 600 f.p.m. They are careful to stress the fact that the development and use of their cemented oxide is in roughly the same stage as were carbides in the year 1930.

When evaluating the performance of Carboloy 030 in comparison with their carbide grades, they have been careful to test against the hardest grades of carbide and not against the heavy duty and relatively softer grades.

In many cases, they consider oxides and carbides as being complementary to each other and this is shown on a job where the facing of a 12 in. diameter blank in AISI.6145 steel (approximately EN.50), using a depth of cut of $\frac{1}{16}$ in. and a feed of .0015 in., is carried out using carbide from the centre of the blank to a diameter where the cutting speed is 600 f.p.m. At this point, oxide takes over for the remainder of the cut to the periphery, where the cutting speed is 2,600 f.p.m.

In this way a considerable reduction in production time was achieved on the component, as the carbide and the oxide were enabled to work at their optimum ranges of speed 2. This is analogous to the combination of high speed drills and boring tools, with tungsten carbide turning tools.

Whilst their oxides have been restricted to light cuts, a specially constructed tool holder (Fig. 4) has been used to cut AISI.1045 (EN.8) at 1,000 f.p.m., at $\frac{1}{4}$ in. depth of cut and $\frac{1}{32}$ in. feed per rev., which cut absorbed a total of 75 horse power 3; rarely is the power available for this kind of machining.

On a production set-up, a change from carbide to Carboloy 030 on the machining of camshafts increased tool life from 800 components per cutting edge of insert to 9,000. To achieve this, however, very careful attention had to be paid to the rigidity of the set-up, with the workpiece supported as closely as possible to the cutting area. In this application, 030 oxide chipped at the cutting speed normally used for the carbide grade (260 f.p.m.), and after experiments 500 f.p.m. was selected for the oxide tip; whereas the carbide tips exhibited some cratering after 50 - 75 components at this stage, the oxide tips exhibited edge wear only 4.

In order to compare the relative life at various cutting speeds of both oxides and carbides, tests were taken on AISI.1045 material (EN.8). In this

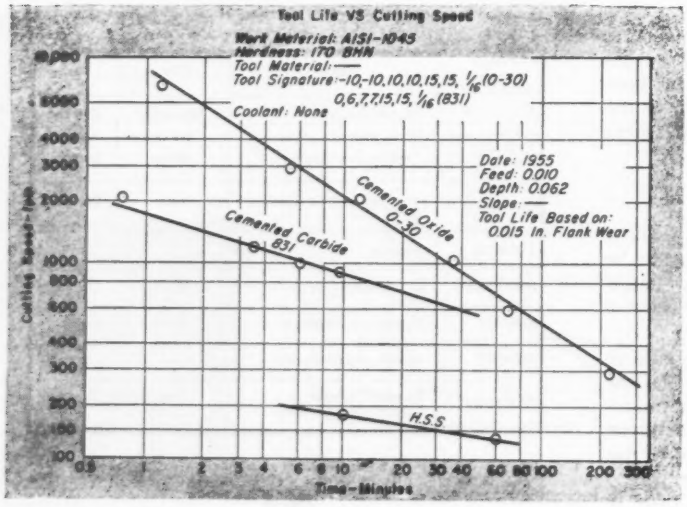


Fig. 5.

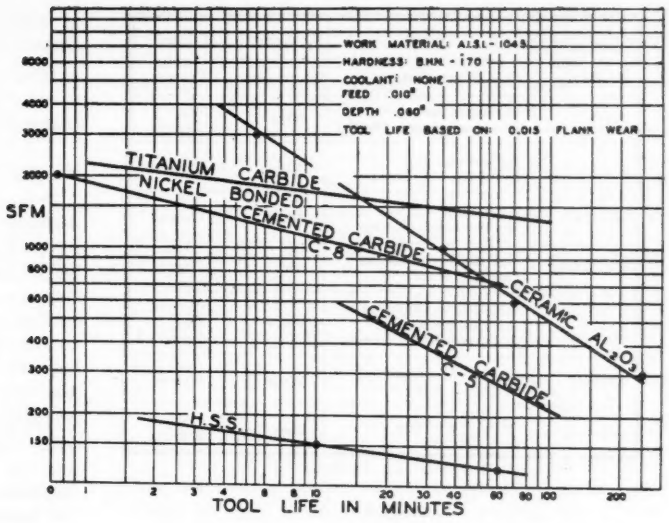


Fig. 6.

case 10° negative rake was used for the oxide tool and 6° negative rake for the carbide tool, with depth of cut at $\frac{1}{16}$ in. and feed .010 in. per rev., the controlling wear land being .015 in. throughout. On the basis of this test it will be seen in which speed range oxide shows advantage (Fig. 5) 3.

This experiment has also been made by us, using Wimet oxides and carbides, and will be referred to later in this Paper.

2. *Warner & Swasey*

The Research Department of Warner & Swasey, at Cleveland, have carried out investigations not only into the relative merits of oxides versus tungsten carbides, but also against nickel bonded titanium carbides (Fig. 6).

It is significant, too, that their work has also emphasised the variations that exist between the performances of oxides manufactured by different suppliers in the U.S.A. The differences in results from the oxide grades are shown to be much greater than one would expect to find between four competitive carbide grades.

Warner & Swasey are convinced that oxide as a finish turning tool, and working on uninterrupted cuts, has found its place in American industry, mainly because of its high "welding on" temperature. They believe that the use of an edge land approximately 30° from the vertical and ground to a width of approximately 80% of the feed, works well in increasing tool life and resistance to edge chipping (Fig. 7). There are no figures available on power absorption.

They consider that coolants have little effect on tool life and may be used or not as desired. It is also claimed that due to the better finish sometimes obtained with oxides, considerable gains can be achieved on materials harder than 380 Brinell, and that they offer advantage where it is possible to impart such a high finish as to replace grinding operations.

Warner & Swasey point out that higher cutting speeds are not the complete answer to the problem of obtaining greater production efficiency and lower metal turning costs. In many cases the time consumed by a machine tool in actually removing metal represents but a small proportion of the overall floor to floor time. Equally important factors are the machine handling time, the work handling time and the setting up time 5.

3. *Massachusetts Institute of Technology*

Most of the work done by the Massachusetts Institute of Technology has been in regard to surface finish. Where cutting speeds are high and the formation of built-up edge is small, the surface finish produced by either carbide or oxide is much the same.

The build-up produced at low speeds on oxide cutting edges is less stable than that produced on carbide edges and, in conjunction with the brittleness

30°
80% OF FEED AT 30°
USE OF EDGE LAND ANGLES GROUND TO A WIDTH OF 80% OF THE FEED AT 30°
PROVIDE - GREATER CHIPPING RESISTANCE -
INCREASED TOOL LIFE

Fig. 7.

	Product Name	Maker	Colour	Type
*	BOLOXIT	Gebr. Böhler, Germany	Light Grey	Clamped
	CEROC	Compagnie Generale D'Electro-Ceramique, Paris	White	Slug. Clamped.
*	DUROX	Duria-Werke, Karl Kempf G.m.b.H., Germany	White	Clamped
*	HARITH	V.E.B. Hardmetal, Immelborn, E.Z. Germany	White	Clamped
*	SECORAMIC	Fagersta Bruks Aktiebolag, Fagersta, Sweden	Black	Clamped
	S.P.K.	Feldmühle Südplastic und -Keramik G.m.b.H., Plochingen/Neckar, Germany	White	Clamped. Slug type.
*	TITOXIT	Deutsche Edelstahlwerke, Krefeld, Germany	White	Clamped
*	WIDALOX	Krupp Widia-Fabrik, Essen, Germany	Light Grey	Clamped & Brazed

* Manufacturers of Carbides

Fig. 8.

of oxide, causes severe chipping if the tools are operated at low speed in the presence of built-up edge.

The ductility of the chips from an oxide edge has been found in some cases to be greater than that produced from a carbide edge, and this suggests that a somewhat higher operating temperature is present at an oxide cutting edge 6.

Previous investigations by M.I.T. into the temperatures produced at the cutting edge have not shown agreement with figures established in Russia. The Russians use the method of embedding thermocouples into the cutting tip in the chip/tool contact region, where they have recorded higher temperatures for cemented oxides than for carbides. Current M.I.T. experiments are being carried out by measurement of the thermoelectric electromotive forces produced at the chip/chipbreaker interface, but final conclusions have not yet been reached.

It would seem to us that the cutting speed determines the temperature at the edge more than the material used for cutting.

4. *Watertown Arsenal*

Watertown Arsenal have for some years been actively engaged on evaluating oxide tooling and have acquired new plant for this purpose. They have been particularly interested in the machining of titanium and other high temperature alloys, but results have not been good, indicating that the high cutting pressures involved with these materials are beyond the present limits of strength of the oxides used.

They have done some work milling with sintered oxide inserts, either in the form of inserted clamped tips or bonded tips. The initial tests were on aluminium and phosphor bronze, although cast iron has been cut at 2,300 f.p.m. They feel that a great deal yet needs to be done on tool geometry and are awaiting arrival of a new milling machine in order to obtain improved rigidity.

Their opinion on oxide again confirms the general view that it will augment conventional tooling and not replace it, and they think that there is the need for the same educational approach in the use of this material as was essential in the introduction of tungsten carbide 8.

(b) *European*

In Europe, development stems from the DEGUSSIT tool demonstrated at the Leipzig Fair in 1937. Then, as today, experiments were made with additives such as silicic acid, chrome and magnesium oxides, and also the borides and carbides of molybdenum, in an effort to vary and improve the properties of the mixture.

The bulk of the post-war work for oxides has been done in Germany, where all the major hard metal manufacturers have produced and are testing oxides (Fig. 8).

Many of these were exhibited at the recent Hanover Fair, but few applications extended the oxide tips. These performances (Fig. 9) relative to those shown by Wickman at the same Fair, give an indication of the present wide variation of opinion concerning the best application of oxides.

Maker	Name	Tool Type	Material	Speed Ft/min.	Feed ins/rev.	Depth ins.	Machine and Operation
Krupp	Widalox	Brazed 45° app. 30° c.r.	Steel C60 51 tons/ sq. in.	472	·008"	·080"	Flycutting Block, 45° entry angle. Tool on headstock VDF. Lathe.
DEW	Titoxit	Clamped Flat Tip	Steel CK60 60 tons/ sq. in.	1640	·006"	·040"	Plain turning. VDF. Lathe (Max. 6,000 revs.).
Fagersta	Secoramic	Clamped Flat Tip	Steel C60 51 tons/ sq. in.	984	·004"	·040"	Plain turning. V.D.F. Lathe.
Feldmühle Südplastic	S.P.K.	Clamped Slug Inserts	Steel CK40 35 tons/ sq. in.	656	·009"	·080"	Plain turning. Lange Lathe.
Duriawerke	Durox	Clamped Flat Tip	—	—	—	—	No demonstration. Recommendation : Steel 1,950 ft/min.
Generale D'Electro-Ceramique	Ceroc	Clamped Slug Inserts	Steel CK40 35 tons/ sq. in.	984	·016"	·040"	Plain turning.
Böhler	Boloxit	Clamped Flat Tip	Bearing Steel 83 t/sq. in.	1740	·004"/ ·008"	·080"	Plain turning.
Wickman	Wimet S.O.	Clamped Flat Tip	34 Ni. Cr. Mo. 6 . 63 t/sq. in.	1950	·0075"	·040"	Plain turning.

Fig. 9.

For our consideration of progress in Europe, we propose to refer to three sources of information :-

1. Krupp Widia-Fabrik;
2. Aachen Technical High School;
3. Compagnie Génerale d'Electro-Ceramique.

1. *Krupp Widia-Fabrik*

Krupp Widia-Fabrik have probably done most work among the hard metal manufacturers in Europe and have compared the relative performance of their oxide and carbides.

The present position with regard to the development of Widalox is such that it is considered to provide a useful supplement to already existing carbide grades, in particular for high speed finishing operations. The fact that it is a useful supplement and not a panacea for all machining troubles is strongly emphasised.

Approximately 60 German firms have tested Widalox under actual workshop conditions and on normal machine tools. Of these 50% have already reported negative results, whereas the remainder are continuing to experiment.

In three cases Widalox has found permanent application in industry, but none of these can be considered as normal jobs on normal materials. These applications are as follows :-

Nyhapren 3767 (Neoprene) is a very hard synthetic rubber with various abrasive inclusions. Widalox, operating at 1,500 f.p.m., with depth of cut .035 in. to .055 in. and feed of .005 in. per rev. is giving 10 times the tool life previously obtained with Widia 'H3' at lower speed.

The finish turning of rubber rolls has also been successful and where Widalox has replaced a diamond tool, similar tool life was obtained using Widalox at 890 f.p.m., with a depth of cut of .024 in. and a feed of .008 in., enabling a large reduction in tooling costs to be made.

The rough boring of lead bronze bearing bushes is also carried out with Widalox under production conditions at 1,400 f.p.m., with a depth of cut of .080 in. to .120 in., giving a tool life of 78 minutes.

Only a small percentage of all the shop tests using Widalox have yet led to permanent application under mass production conditions. They find that the type and condition of the average machine tool is not conducive to the exploitation of sintered oxide and in some cases have found it necessary to re-bed the whole machine in order to reduce vibration. They point out that, other factors being equal, the horse power required for metal removal increases approximately in proportion to the cutting speed.

An attempt at turning highly abrasive aluminium alloy pistons of high silicon content was unsuccessful, as severe built-up edge prevented the required surface finish being obtained. Experiments are continuing on a wide range of synthetic materials and on hardened steels and cast iron.

As far as copy turning is concerned, they have obtained no consistent result up to the present time. They point out that although one firm did in fact demonstrate copy turning with an oxide at the Hanover Fair, it should be borne in mind that months of preparation would be necessary to perfect this one application.

Experiments are being conducted with milling and some tipped slab mills have been made on which interesting results are being achieved, but which are in too early a stage of development to report here.

Turning of hardened steel has been attempted on a ball race steel of 750 VPN. The application of Widalox appeared to be successful until small cracks present in the surface of the workpiece caused immediate failure of the cutting edge 9.

2. *Aachen Technical High School*

Under the direction of Professor Opitz, useful work has been done in comparing competitive oxides and most of the current European makes have been evaluated in terms of their relative performance. Here again there is emphasis on the variation in performance between different makers' grades.

Experiments in the past had shown that thermo-electric currents induced in a carbide tip were responsible for some of the tool wear. Such an induced current may flow in either a positive or a negative direction. In a set-up designed to measure this, a typical current was measured of 5 ampères at 6 to 10 millivolts. Insulation of the carbide tool within its holder stopped the circulation of this current and contributed to an immediate increase in tool life. Since an oxide tip is already a good insulator, this problem is not expected to arise.

An extensive programme of tests was carried out machining steel similar to British Specification EN.8 and whilst some of the grades failed completely, one group showed some advantage when compared with Widia Grade 'L1' Carbide, mainly due to the excessive flank wear of the carbide at the speeds being used.

A number of the oxide grades showed a marked reduction in flank wear, the actual amount varying between each grade and it was found in these cases that an increase in cutting speed of 50% could be obtained for the same edge wear as with carbide if the feeds were limited to a maximum of .020 in. per rev.

The most notable advantages were seen in respect to crater wear. Although in several cases with oxide, cratering was present where the top rake was 6° positive, it could be safely ignored, as in no case was it the factor responsible for breakdown. In contrast to this, cratering was the limiting factor in tool life when using carbide grade Widia 'L1' at the higher speeds.

Their power consumption readings showed an increase of some 15% to 20% for oxide over carbide tooling, but some of this would be due to the fact that different tool geometry was used in the tests and it is difficult to estimate how much of this

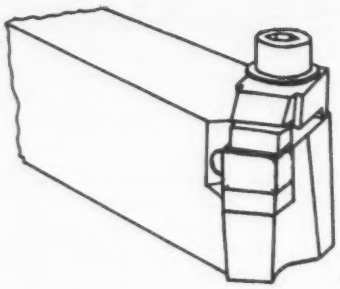


Fig. 10.

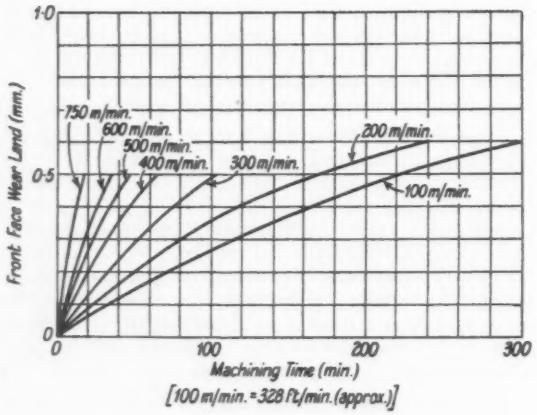


Fig. 11.

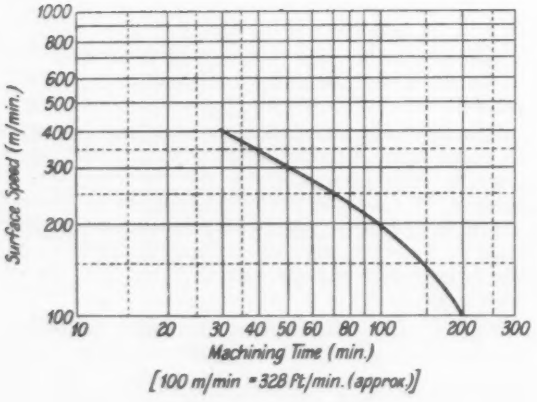


Fig. 12.

power increase was due to this change in geometry.

In the machining of cast iron, both with and without casting scale, they found that the oxide tools performed well, and in most cases better than the carbide grade normally used for the operation, even where the nature of the material made great demands on the tool due to the uneven surface and out-of-roundness of the component [10].

3. *Compagnie Génerale d'Electro-Ceramique*

In France the Compagnie Génerale d'Electro-Ceramique have developed an oxide which they call "Céroc". Fig. 10 shows their design of tool holder arranged for mechanical clamping of the sintered oxide tip. It will be appreciated that only half of the shank section is effective, due to the great thickness of the slug type insert and the carbide anvil and chipbreaker.

Curves showing the relative amounts of wear land on Céroc in relation to surface speed and machining time have been established (Fig. 11).

The curves of surface speed and machining time in relation to a fixed flank wear land have also been established for Céroc (Fig. 12).

They are of the opinion that although manufacturers at the moment are concentrating on the production of one grade of tip, it will be necessary for various grades of tips to become available in the same way that alternative grades of tungsten carbides are available to suit different applications.

An interesting aspect of their work has been an investigation into the variation in flank wear land experienced when using either stoned or unstoned cutting edges, which serves to emphasise the importance of stoning the cutting edge prior to use, particularly at the higher cutting speeds (Fig. 13) [11].

(c) *Russian*

The Russian tool materials are very fine grain aluminium oxides pressed and sintered, probably with binding agents.

The two materials generally available are named Thermokorund and Microlit, with relative physical properties as shown in Fig. 14.

These materials being of extremely high hardness are also very brittle and chipping of the cutting edge is the limiting factor in their use.

Tests taken on nickel chrome steel of 240 Brinell, using Microlit, produced the curves shown in Fig. 15. Variations in speeds, feeds and depth of cut were made and it should be noted that in all cases there occurred a period of rapid wear followed by a period of zero wear, with the steps in the graph indicating where chipping has taken place. This is synonymous with our experience with carbides.

Comparisons have been made in the performance of Microlit against a Russian carbide grade 'T.15K6', with the result shown in Fig. 16. Test work has also been done to show the effect of porosity on tool life, the results of which make it evident that the smaller the porosity the longer the tool life, which points to the desirability of an oxide of very high density (Fig. 17).

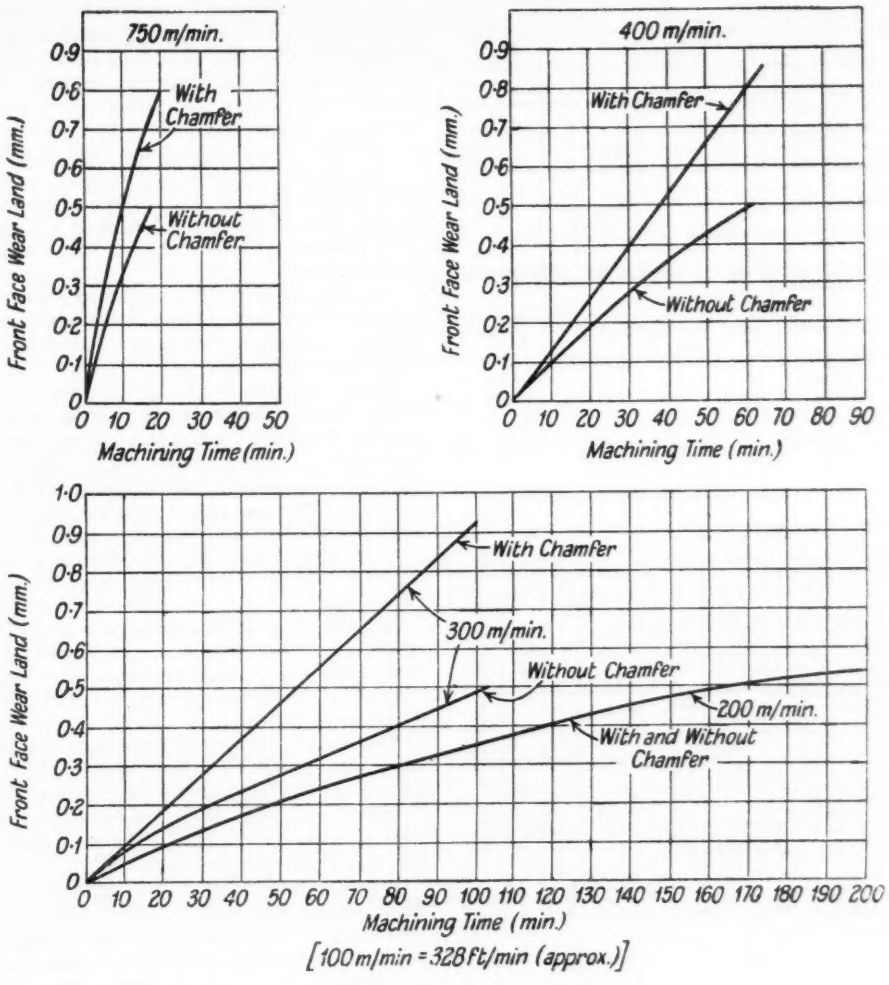
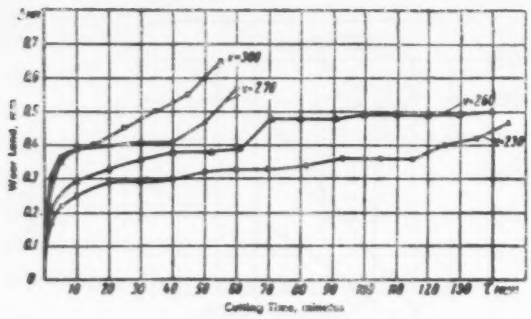


Fig. 13.

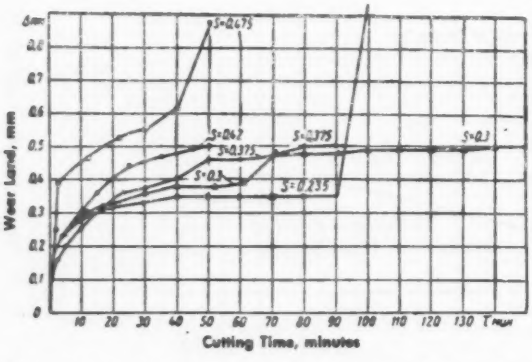
PHYSICAL PROPERTIES

Material	Russian Designation	Specific Heat Cal.g.Deg.C.	Conductivity Cal.cm.sec. Deg. C.	Specific Gravity	Coefficient of Thermal Exp. Deg. C.	Hardness R_A	Bending Strength Kg. per sq. mm	Compressive Strength Kg. per sq. mm
THERMOKORUND	TW-14	·18	·01 ·0055	3·9 3·75	7·9 x 10^{-6}	86-88	30	90-150
MICROLIT	ZM-332	—	—	3·96	—	91-93	40-45	500
	Microlit is 99-99·2% Al_2O_3 with grain size of 1-3μ							
SINTERED CARBIDE	T15K6	·06	·065	11·0	5 x 10^{-6}	90·2	115	400

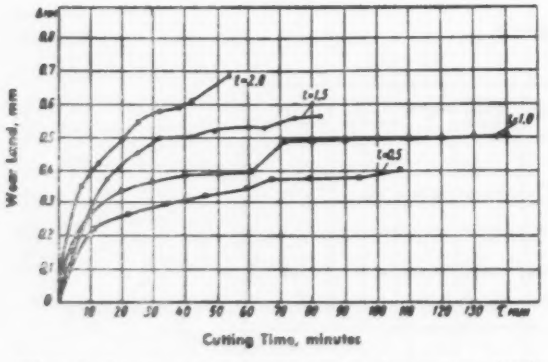
Fig. 14.



Wear land versus cutting time curves for various cutting speeds (V, m per min.). Tool: ZM-32; depth of cut: 1 mm; feed: 0.3 mm per rev.



Wear land versus cutting time curves for various feeds (S, mm per rev.). Tool: ZM-322; speed: 260 m per min.; depth of cut: 1.0 mm.



Wear land versus cutting time curves for various depths of cut (t, mm). Speed: 260 m per min.; feed: 0.3 mm per rev.

Fig. 15.

In order to indicate the effect of continual start/stop conditions of machining, which in general affect wear more than the total amount of metal removed, results were plotted (Fig. 18) to show the effect on life of cuts which were interrupted every minute, every five minutes and every 10 minutes.

Russian opinion is that the type of chip produced by oxide and carbide tools is essentially the same, but that friction between the surface of an oxide tip and a steel chip is somewhat less than for carbide. This they think means a lower power consumption per unit metal removed.

To this end they have produced a curve indicating the power per unit volume of metal removed, plotted against the normal cutting speeds for oxides, carbides and high speed steels (Fig. 19).

Their work has shown that the tool/chip interface temperature is higher when cutting with oxide, due to the lower thermal conductivity, and has been estimated as being about 30% higher than that normally associated with a carbide edge. They state that in some cases the temperature is sufficiently high for plastic deformation to take place [12].

The relationship between cutting speed and tool life for various materials has also been determined (Fig. 20).

A Table (Fig. 21) has been produced of speeds and feeds against variations in the depth of cut when machining a 47-ton plain carbon steel with Microlit CM.332 and without coolant, the tool life being kept constant at 90 minutes.

The Russians say that from tests carried out they have established that the feed should not exceed .024 in. to .026 in. per rev. It is suggested that the depth of cut with their oxides should not exceed .160 in. with a reduction if the feed used is towards the maximum recommended.

Where surface finishes of a high order are required they recommend that the feed should not exceed .004 in. to .006 in. per rev. with as high a cutting speed as is consistent with reasonable tool life.

Although the Russians have been successful in developing a brazing operation and were, we believe, the first people to do so, they still appear to rely on clamped tips to a large degree and Fig. 22 shows two typical designs. In each instance, a shim of brass is placed between the tip and the anvil to reduce the production cost of grinding these mating faces.

The second tool shows a tangential presentation of the tip within a cantilever holder, the interesting point being the method of retaining the insert by means of a small wire and the reliance on the actual cutting forces to keep the insert in position during operation [13].

(d) *British*

The following manufacturers in England are at the present time experimenting with and developing oxide tools:

Lodge Plugs Limited, Rugby

Their Sintox materials are used in a slug form in a steel holder and are generally in the unground condition (Fig. 23). The cutting speeds shown in

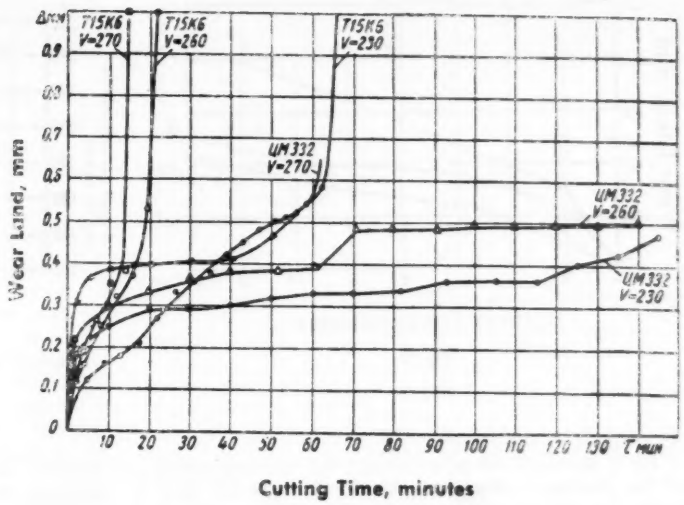


Fig. 16.
Comparative wear curves for ceramic tool ZM-322 and carbide tool T15K6 at various cutting speeds. Depth of cut: 1.0 mm; feed: 0.3 mm per rev.; speed: Vm per min.

Fig. 24 14 have been recommended for roughing and finishing with Sintox, and a study of these recommendations will show that at some of these speeds carbides are already firmly established.

Firth Brown Tools, Sheffield

Firth Brown Tools have developed an oxide described as "Speedicut 101", which is generally recommended for use in a mechanical holder (Fig. 25).

It will be noted that no provision is made for chip control in this design of tool, which it is intended should be carried out by variation of the feed/depth of cut ratio. This is because their early investigations suggest that a chip-breaker, unless critically adjusted, can have an adverse effect on edge life.

They have worked on 220 Brinell cast iron at speeds up to 1,000 f.p.m., with feeds of .010 in. per rev. and depth of cut of $\frac{1}{16}$ in. In this case their oxide tests showed only .013 in. of flank wear after 38 minutes, compared with .033 in. - .078 in. of wear land after 45 seconds using their selected grade of carbide.

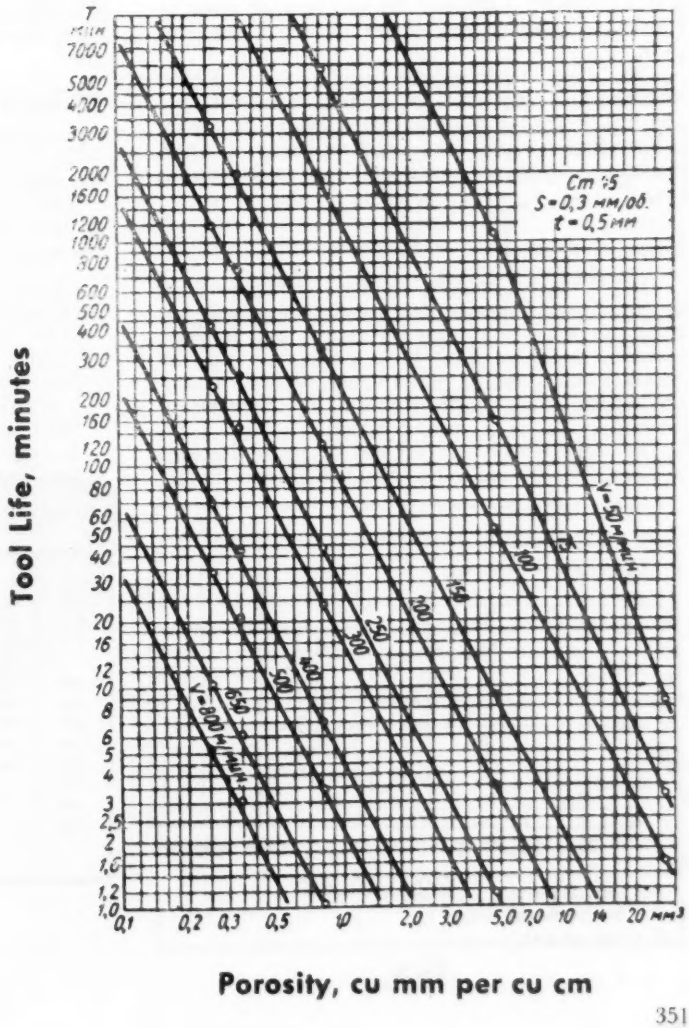


Fig. 17.
Effect of porosity of ceramic tools on tool life at various cutting speeds. Material: alloy steel; depth of cut: 0.5 mm; feed: 0.3 mm per rev.; speed: Vm per min.

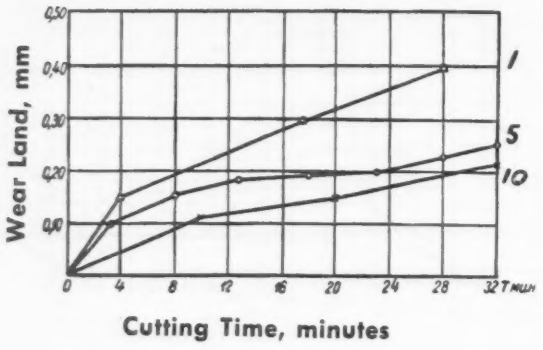


Fig. 18.

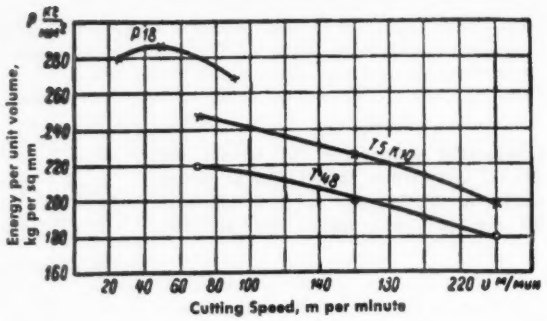


Fig. 19.
Energy per unit volume for different tool materials.

Their standard set of conditions for the evaluation of the quality of laboratory-produced batches of their oxide are set on mild steel of .2% carbon content and 150 Brinell hardness, the cut to take place at 1,500 f.p.m. with a feed of .006 in. and a depth of $\frac{1}{16}$ in.

They have reported the machining of EN.18 material, heat treated to 250 Brinell, at 1,200 f.p.m., and EN.23, treated to similar hardness, at 800 f.p.m.

Firth-Brown report disappointing results in finish machining austenitic stainless steels up to the present time 15.

Wickman Limited

The Wickman interest in the development of sintered oxides has been intermittent since 1942, but it has for some time been quite clear that facilities normally available have been inadequate for the accurate evaluation of performance possibilities and for determination of the technical requirements of sintered oxides as a cutting material.

The work already carried out by world interests just described demonstrates the uncertainty of fundamental data generally available. We, therefore, decided to equip our Research Department with machine tools specially developed for the purpose. The following section of the Paper deals in detail with this equipment and the use to which it is being put.

Wickman progress

(a) *description of equipment recently installed*

test lathe (Fig. 26)

After very careful study of the problems presented by very high speed test turning, we selected the following basic specification for our test lathe :-

Height of centres : 16 in.
Distance between centres : 5 ft.
Speed range : infinitely variable, 500 to 5,000 r.p.m.
Later provision for 5,000 to 10,000 r.p.m. by substitution of unit headstock.
Main motor : 40 h.p. D.C.
Tailstock : hydraulic.
Running centre : special heavy duty type.

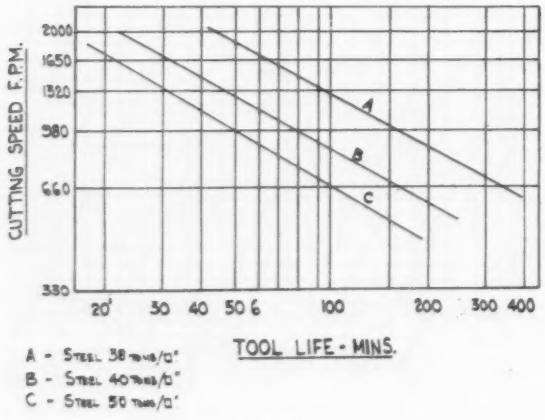


Fig. 20.

Depth of Cut in ins.	Feed Range in ins/Rev.							
	.004"	.006"	.0078"	.0098"	.0118"	.0157"	.0196"	.0236"
	Speed Range in s.f.p.m.							
.0196"	1130	1070	1025	990	960	—	—	—
.040"	1085	1035	985	960	935	—	—	—
.060"	1070	1010	965	635	915	875	—	—
.080"	1055	995	955	925	900	860	830	—
.100"	1045	985	945	915	885	850	820	700
.120"	—	975	935	905	880	840	815	795
.160"	—	965	925	895	875	830	805	775
.200"	—	—	915	885	865	825	795	770

Fig. 21.

The 40 h.p. D.C. motor of the shunt type is controlled by a thyratron valve arrangement to give a variable speed of the motor of 375 to 3,000 r.p.m., controlled in the ratio of 1 : 8.

The range of speeds obtainable from the present unit headstock is infinitely variable between 500 and 5,000, and at a later date another headstock can be substituted which will increase the maximum r.p.m. to 10,000.

Any preset cutting speed up to 2,400 f.p.m. is constantly maintained by automatic potentiometer control in the cross slide. The saddle is fitted with a rapid traverse of 10 f.p.m. in either direction, and is provided also with micro turret stops so that six successive test cuts can rapidly be made.

Should the spindle speed be regulated independently of the cross slide, then cutting speeds up to 30,000 f.p.m. could be obtained. The spindle, which is dynamically balanced, is mounted in specially designed 8 in. diameter bearings and lubricated by an oil mist system.

The motor and pulley are dynamically balanced and are mounted on a foundation which is insulated from the surrounding ground and from the main bed foundation, which itself is also insulated from the surrounding floor.

The specially designed running centre, suitable for the loads to be imposed at 5,000 r.p.m., is carried in a rigid tailstock which is hydraulically operated so that constant pressure can be maintained at the centre irrespective of any lengthening of the workpiece due to expansion.

To prevent vibration and provide safety at high speed, a new type of collet arrangement of the Ringspann type is employed on the machine. A dual range of feeds is provided from .001 in. to .028 in. per rev., either being selected by electro-mechanical clutch from a switch on the saddle of the machine. These feeds can be further augmented as required by changing the feed gear ratio in the normal way.

The machine bed is of exceedingly rigid construction with triangular wall sections, the swarf tray being integral with the main casting to further assist vibration-free running. Careful attention was paid to the provision of adequate swarf clearance through the bed, and the tray slopes to the rear to facilitate easy exit of the chips.

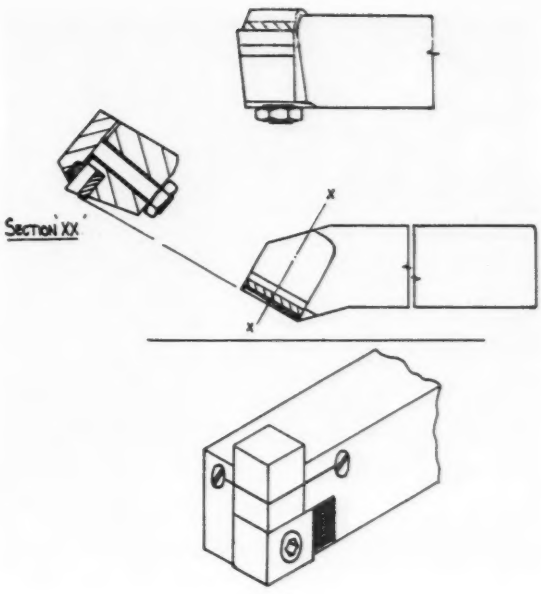


Fig. 22.

An aerodynamic fan, mounted coaxially on the main motor, blows cooling air over the motor and down the length of the lathe, to be expelled through grilles in the end of the bed.

The cross slide is specially designed to cater for normal cantilever or, alternatively, tangential type tooling. The spindle of the machine is adapted to take a milling cutter so that experiments in flycutting and multi-tooth milling can also be carried out with

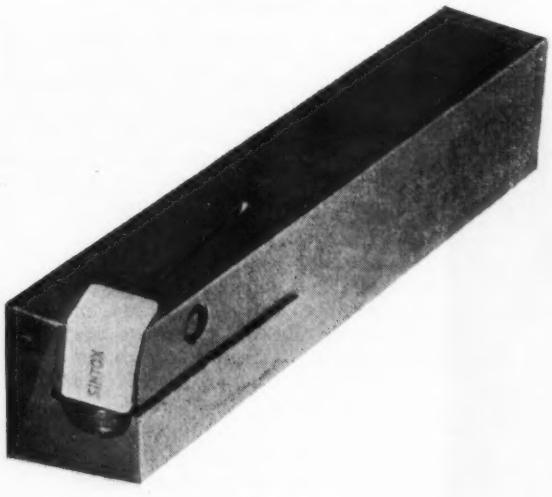


Fig. 23.

Material	Roughing Ft/Min.	Finishing Ft/Min.
Up to ·2 Carbon Steel	400—800	1,000—1,300
·2—·3 Carbon Steel	300—600	800—1,000
·3—·4 Carbon Steel	250—500	700—900
4—·6 Carbon Steel	200—300	400—600
Close Grained Cast Iron Brinell Hardness 217	500—1,000	1,000—1,500
Commercial Brass	Unlimited, dependent on motor speed and power available.	
Aluminium	Unlimited, dependent on motor speed and power available.	

Fig. 24.

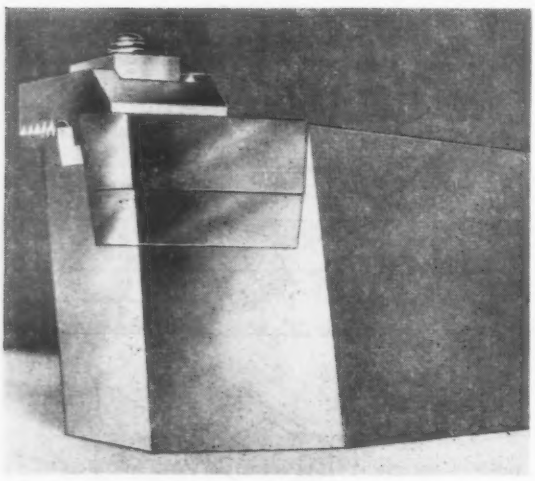


Fig. 25.

sintered oxide tools. Tee slots provided in the cross slide provide the means of bolting the test block holder.

Instruments for recording r.p.m., cutting speed, amps. and kilowatts are grouped in a panel to the left of the headstock. On a separate instrument table, insulated from the floor, there is recording equipment for the cutting forces measured by the tool force dynamometer, which is of the latest German electrical type. Also mounted on this table is a Taylor, Taylor & Hobson, Model III Talysurf instrument, with rectilinear recording equipment for the measurement of the surface finishes produced on the workpieces.

milling machine (Fig. 27)

The Heller range of milling machines is very well known. The standard FH.160 production machine already provided most of the features which we sought in a development machine, and it was only necessary to obtain certain modifications in order to achieve features which were considered necessary for research and development purposes.

The main drive is of 45 h.p. and the drive is transmitted to the machine through an 18 speed gearbox. This provides a range of speeds from 28 to 900 r.p.m., which are selected by electro-mechanical disc clutches, the spindle being provided with a brake to reduce running down time.

Movement of the table and knee is effected by mechanical leadscrews driven by hydraulic motors, with full compensation for climb milling. The table is supported at four points in addition to the central elevating mechanism, and during the cut is hydraulically clamped to these four points for maximum rigidity.

The table feed along and across is infinitely variable between $\frac{3}{4}$ in and 140 in. per minute, and up to 35 in. per minute in a vertical direction.

The complete control system for the machine is grouped on a panel at the front of the machine, which has a total weight of some 13 tons and is mounted on a substantial bed insulated from the surrounding ground.

(b) *results so far achieved on these machines and in the field, with comparisons against carbides*

materials used for tests

As a start it is necessary to select the types of materials for the test billets and to decide what forms these billets should take.

Although all types of material are tested from time to time, the bulk of our results is obtained using the following specifications :-

EN.8 — (.4% carbon steel in the 35-ton condition).
EN.18 — (1% chromium steel in the 45 - 55 tons condition).
EN.24 — (1½% nickel chrome molybdenum steel in the 50 - 60 tons condition).
BS.1142 — (Grade 20 Cast Iron).

As is known, the addition of chromium to steels reduces their machinability and EN.18 is less readily machinable than most. It causes severe abrasion of the cutting edge so that a measurable tool wear can be produced quickly with a consequent saving in volume of test material used.

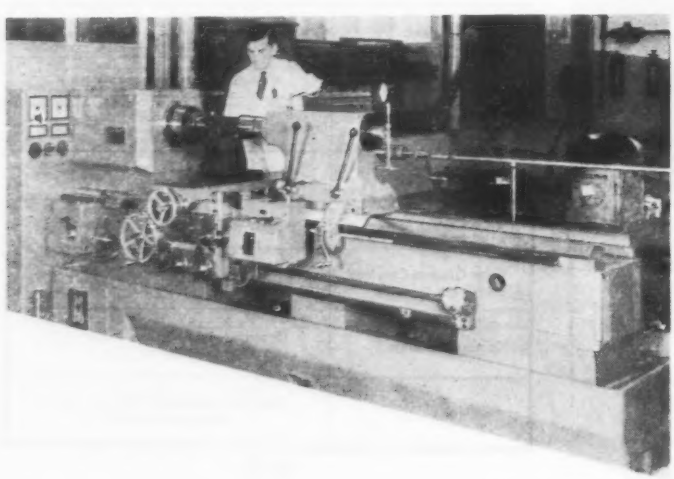


Fig. 26.

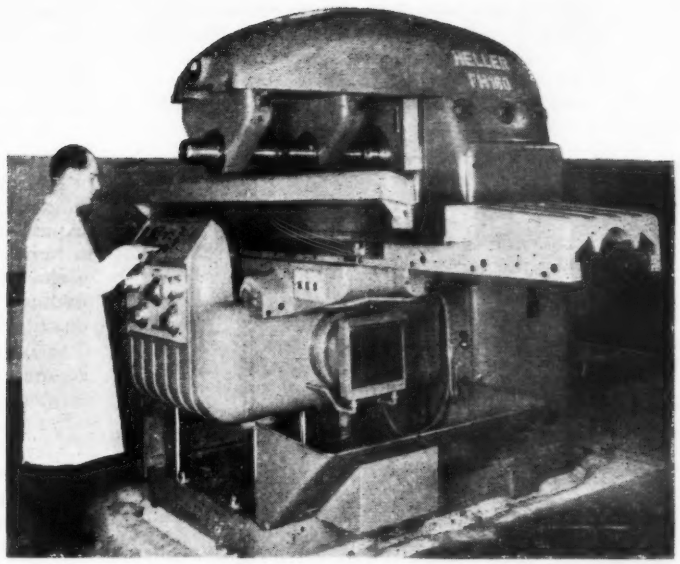


Fig. 27.

EN.24 is representative of the wide range of alloy steels containing nickel chromium and molybdenum, and EN.8 is provided for test since so much work is done in industry using steels of the plain carbon type, the cast iron specification being selected for the same reason.

TURNING

The test billets are prepared in several different forms so that the cutting edge may be subjected to controlled variation of those conditions usually encountered either singly or collectively in the machine shop.

(1) Plain billet — previously machined surface
A number of published tests have quoted results which have been obtained using large diameter billets at relatively low spindle speeds in order to provide suitable surface speeds for the test, and elsewhere the performance of oxide has been to some extent accepted on the basis of workpieces of extremely large diameter/length ratio.

In view of the high speed range made available on the Müller lathe, it was desirable that the billets should be chosen with a diameter/length ratio more consistent with the type of job normally encountered in the machine shop.

At a later stage it is our intention to compare performances over a wide range of diameter/length ratios, but those we use at the present time range between the ratio of 1 : 6 at 4 in. diameter to 1 : 12 at 2 in. diameter. This type of billet, 4 in. diameter × 24 in. long, is used for normal metal removal tests to establish life and geometry. It is also suitable for tests using the dynamometer and is the simplest form of test billet.

(ii) Grooved billet
It has been our experience in testing tungsten carbide tools that repeated entry by the cutting tool has more effect on tool wear than the length of cut. A considerable amount of wear takes place at the initial stage of entry when the elastic deformation of the workpiece causes rub at the cutting edge, producing a fine dust before a complete chip is produced. A grooved billet is used in order to simulate repeated entry into the workpiece without having the trouble of disengaging the cut. It should not be confused with interrupted cutting, as the lead in of the cutting edge to the cut is helical and smooth.

(iii) Slotted billet
A billet, in which have been milled radial slots along its length, provides mechanical shock load conditions and a useful method of exploring refinements in tool geometry to overcome these conditions in either milling or turning operations.

Such a billet cannot simulate the degree and variation of thermal shock which is present in milling operations, since a tool in this case is more "in cut" than "out of cut". Variations can be introduced by altering the number, width and spacing of the slots to follow more closely milling practice, for example, in face milling where the recommended entry angle is 45°.

A slotted billet also provides the arduous conditions necessary when testing various ways of holding a tip, either by clamped, brazed or bonded methods.

(iv) Eccentric billet
A billet which has been deliberately off-centred is used to simulate the condition where a variable depth of cut provides variable cutting pressures. It enables the optimum depth of shank to be decided and a comparison to be

made between cantilever and tangential tooling. Speeds, of course, are limited and the allowable eccentricity at the higher speeds is relatively small.

The main programme of work on these four types of billet seeks to determine the following :-

1. Optimum tool geometry and relative merits of cantilever and tangential type tooling.
2. The efficiency of comparative methods of holding the tip — clamped, brazed or bonded.
3. Power consumption per unit metal removal rate compared with carbide.
4. Relative general performance of oxide versus carbide to establish best field of application for each.
5. Chip control studies.

1. *optimum tool geometry*

Optimum tool life for oxide is obtained with angles much more negative than those usually associated with carbides (Fig. 28). However, in order to effect interchangeability between oxide and carbide tips within the same holder, it is worthwhile to accept a small loss from optimum oxide life for this advantage. Furthermore, if a carbide tool is already exploiting the power availability of the machine tool to the full, then the additional requirements of power for further negative rake would not be available anyway.

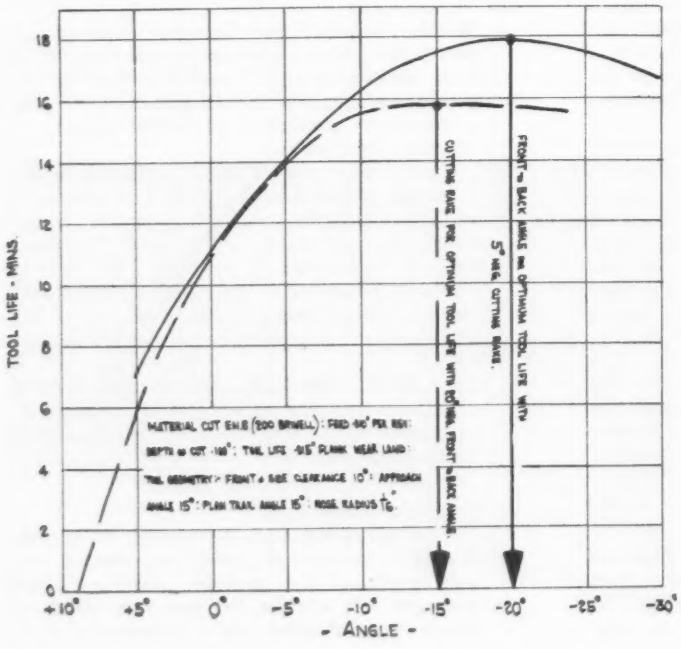


Fig. 28.

In the geometry of oxides there is every indication that stoning of the cutting edge has more effect than it has with carbides. Experience with carbide tools has shown that it is helpful, particularly in machining steels with scale, to stone off the sharpness of the cutting edge. With oxide tools it is imperative to carry out this operation.

Naturally the degree of stoning has a great bearing on the power consumed during the cut, and our experience to date has indicated the superiority of a radius stoned along the cutting edge rather than a chamfer stoned across the edge. In this respect our findings differ from those of Warner & Swasey described earlier.

2. *the efficiency of comparative holding methods*

(a) Clamping

From tests carried out, there are already indications that clamping may be the best method of holding tips. Tool holders utilising slug type inserts have been tried but show two main disadvantages :-

(i) severe damage to any cutting edge often splits the whole slug or flakes it very badly, with consequent waste of a large volume of the oxide;

(ii) ground-in chipbreakers in any oxide tip are undesirable because the friability of the oxide does not lend itself, at this stage of its development, to the sort of pressures which are involved in chip control—furthermore, if the chip groove is to be effective, it reduces the number of cutting edges from 8 to 4.

Consideration could be given to a slug type insert utilising a solid carbide chipbreaker, but this is difficult to achieve neatly in any form of slug type insert as these slugs are invariably clamped on their sides.

The Wickman "Econotip" range of tools has been designed to satisfy these criticisms and to provide an insert of economical volume, with a separate mechanical chipbreaker. The thickness of this insert need only be $\frac{3}{16}$ in. and for light duty work can in some cases be successfully reduced to $\frac{1}{8}$ in. (Fig. 29).

The oxide cutting tip is sandwiched between a carbide anvil and a carbide chipbreaker. This anvil serves to provide an accurate flat seating for the tip and at the same time helps to protect the flank of the tool holder from the erosive action of fast flowing swarf.

The chipbreaker is readily adjustable for various feed rates and can be easily replaced or reground once it has become badly cratered. It also allows the cutting tip to be used on all eight edges with complete chip control for these edges, so that the highest economic advantage is taken of the volume of oxide provided.

The spring clamp need only be finger-tight to keep the tips in place, the cutting forces being absorbed both by the anvil and the hardened steel locating piece which holds the assembly in position.

It will be appreciated that with a clamped tip, be it oxide or carbide, the only stress present is clamping stress and this can to a large extent be controlled and predetermined in its pattern during the design of the clamp.

(b) Brazing

There are occasions where space considerations will not permit of clamping, so that methods of brazing or bonding have to be considered. As with carbides, brazing or bonding operations bring the problem of residual stresses, due to differential expansion during the heating operation.

Obviously when two surfaces with different coefficients of expansion are metallurgically joined together when hot, there is produced, on cooling, considerable stress in the member with the lower coefficient of expansion. Thus some of the strength of the tip is immediately lost as a resistant to cutting forces, as it is already providing resistance to these residual stresses.

There is no doubt that the brazing of oxide is more difficult than with carbide and we are still seeking a better technique. The only pre-brazing preparation necessary with carbide is a careful degreasing operation and application of the flux. When brazing oxide tips, the pre-brazing preparation is considerably complicated and because of these complications, which we will now explain, it will be appreciated that it is difficult to carry out on a production basis.

The tips have first to be carefully examined and then cleaned in acetone. It is then necessary to brush on to the tip a solution of titanium hydride in a mixture of celluloid and amylacetate. The resulting paste is spread evenly over the tip to within $\frac{1}{128}$ in. of the cutting edge clearance faces. The tips are then slowly dried.

Prior to being metallised a thin brass shim, the same shape as the tip, is laid on to this paste. Metallising must be then carried out in vacuum at approximately 1,150°C when the brass melts and combines with the titanium. After cooling, the metallised face is sand-blasted and the tip is then ready for a normal brazing operation, either with silver solder or preferably with tin.

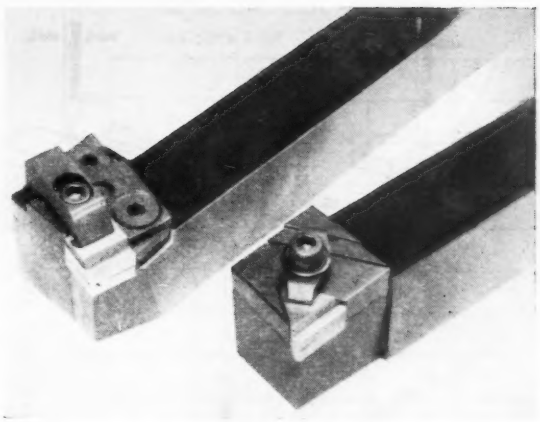


Fig. 29.

On cooling it is necessary to take the same precautions as when carbide tips are cooled from brazing, and this is preferably carried out in a slowly cooling furnace, thus preventing the formation of thermal cracks which will otherwise appear.

The shear strength of such a braze is approximately 5 tons per sq. in., in the brazing zone between the tip and the shank [16].

Since this whole operation is complicated, attention has been diverted to a simpler method and the possibilities of bonding are being investigated.

(c) Bonding

Epoxy resins of various types have been tried, with mixed success. Success has been achieved where the depth of cut and feed are limited and where coolant can be used on the operation to reduce the temperature of the tip at the joint face between the tip and tool shank. Success with bonding depends on a low operating temperature and limited metal removal.

Generally speaking, Epoxy resins are suitable for working temperatures up to 300°C and our work has been carried out with "Araldite" Type I, which is an aluminium filled resin.

The tip and seat are first thoroughly degreased in trichlorethylene and are then rinsed in carbon tetrachloride. The tip and shank are then warmed together and the "Araldite" run on to the surfaces of the faces to be offered together.

Curing must then take place in air at 200°C for approximately 90 minutes, the time being proportional to the area to be bonded.

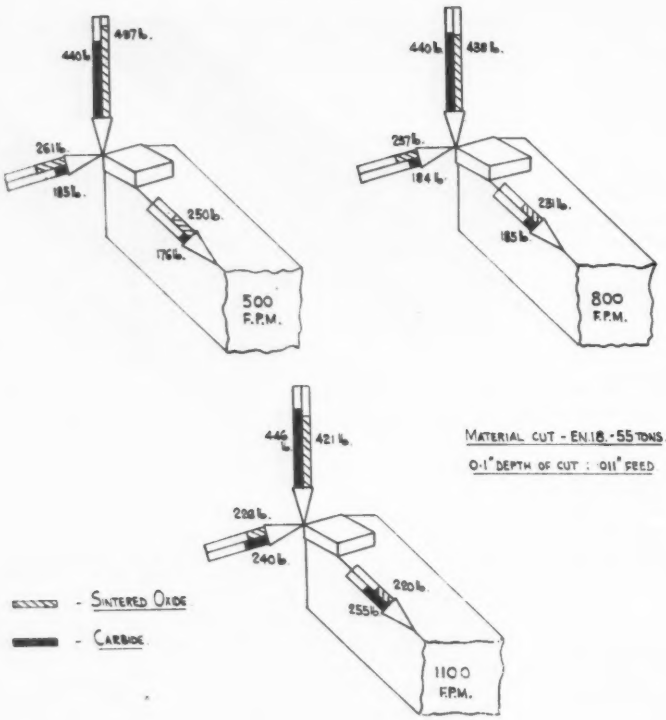


Fig. 30.

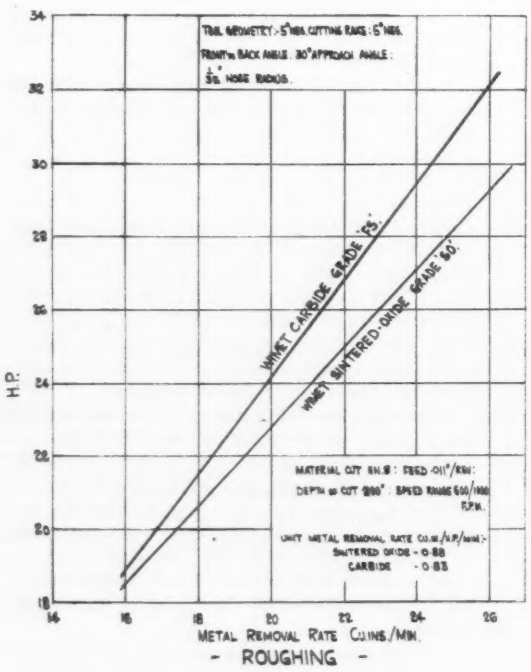

TOOL GEOMETRY :- 5° NEG. CUTTING RAKE : 5° NEG. FRONT to BACK ANGLE : 30° APPROACH ANGLE : ¼" NOSE RADIUS.
WIMET CARBIDE GRADE 'F5'.
WIMET SINTERED-OXIDE GRADE 'S0'.
MATERIAL CUT EN.8 : FEED ·011"/REV : DEPTH of CUT ·200" : SPEED RANGE 600/1000 F.P.M.
UNIT METAL REMOVAL RATE C.I.M./H.P./MIN. :- SINTERED OXIDE - 0·88 CARBIDE - 0·83
H.P.
METAL REMOVAL RATE CU.INS./MIN.
- ROUGHING -

Fig. 31(a).

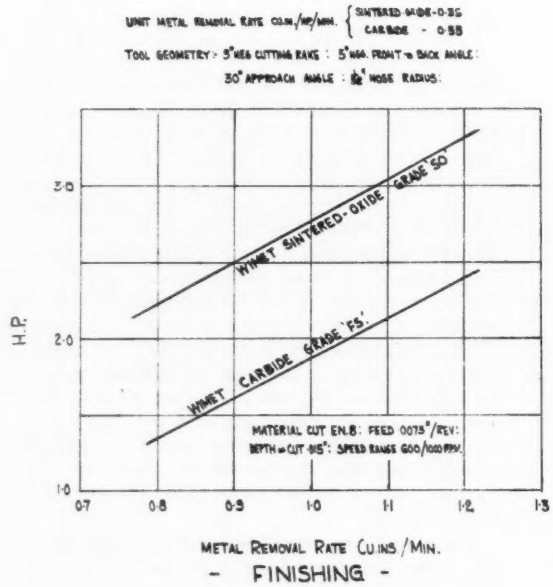

UNIT METAL REMOVAL RATE C.I.M./H.P./MIN. { SINTERED OXIDE-0·85 CARBIDE - 0·88
TOOL GEOMETRY :- 5° NEG. CUTTING RAKE : 5° NEG. FRONT to BACK ANGLE : 30° APPROACH ANGLE : ⅛" NOSE RADIUS.
WIMET SINTERED-OXIDE GRADE 'S0'
WIMET CARBIDE GRADE 'F5'.
MATERIAL CUT EN.8 : FEED ·0075"/REV : DEPTH of CUT ·015" : SPEED RANGE 600/1000 FPM.
H.P.
METAL REMOVAL RATE CU.INS./MIN.
- FINISHING -

Fig. 31(b).

Results so far are promising and we have determined that the maximum depth of cut appears to be .1 in., with feeds per rev. no higher than .005 in. - .008 in. The area of the chip appears to limit the load-carrying capacity of bonded tips irrespective of the cutting speed, but we have much work to do before our observations are complete.

3. *power consumption/unit metal removal*

Using the established clamped tip geometry for carbides, of 5° negative rake, 5° front to back angle and $\frac{1}{32}$ in. nose radius, the actual cutting forces approximate to those for carbides, when the oxide is being operated at somewhere near its optimum speed (Fig. 30). Differences in the recorded figures are no doubt explained by slight variations in the stoning of the cutting edge and it will be appreciated that it is not easy to ensure that the stoning of each edge is precisely the same. To this end, we are investigating methods to produce automatic stoning of cutting edges by a mechanical means.

It is now desirable to compare the performance of oxides and carbides on the basis of metal removal efficiency in both roughing and finishing operations and in the higher speed range as well as in the normal speed range for carbide. The test results are shown in Fig. 31.

Fig. 32 shows the relative performances on EN.18 material at various speeds of Wimet sintered oxide and the present hardest grade of Wimet tungsten carbide (FS), which has a high titanium carbide content. In order to illustrate that the performances achievable with oxides of different makes are widely variable, we have also added to the graph the relative performance of two American oxides which we denote (a) and (b).

4. *relative general performance of oxide and carbide to determine best field of application for each*

Present indications are that oxides will be complementary to carbides and can immediately find a small field of application on modern machine tools for high speed finishing cuts. How large the field of application ultimately becomes will depend entirely on the progress made in machine tool design, and to any further metallurgical developments found possible to enhance the physical properties of the oxide material.

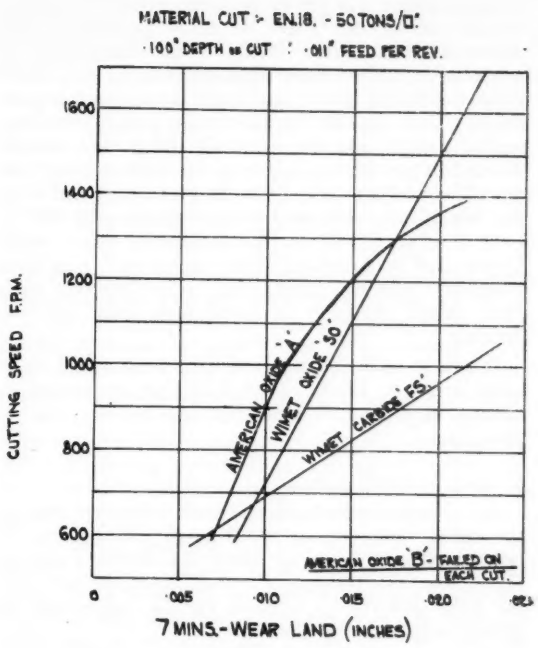


Fig. 32.

It is well known that high cutting speeds usually show an improvement in *observed* surface finish. Since oxide can operate at high speed and at the same time has a high resistance to the formation of built-up edge, it is sometimes possible to produce finishes of such a good surface character as to make possible the elimination of subsequent grinding or burnishing operations. At the speeds within their scope, on materials which can be cut under conditions which minimise the formation of built-up edge, carbides can produce equivalent surface finish (Fig. 33).

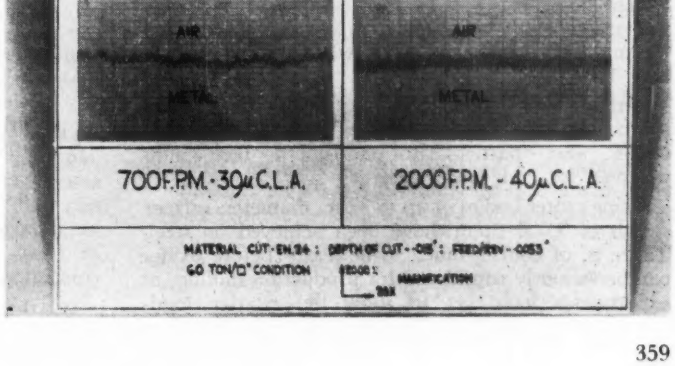


Fig. 33.

A great deal has yet to be learnt about the precise mechanism of the types of wear associated with sintered oxide tooling. There is no doubt that an oxide wear land is more difficult to measure. Under some conditions an "apparent" wear land is produced. This appears to be a film, possibly of iron oxide, which must be dissolved off in hot caustic solution before it is possible to see and measure the actual wear land. It may be lack of appreciation of this fact which explains why wear lands up to .060 in. have been reported for some sintered oxide tools. In this case it is probably the "apparent" wear land which has been measured, when in fact the true wear land would probably be somewhere near half the amount.

It can be said that the true wear land on an oxide edge is not so clearly defined as that on a carbide cutting edge and is more difficult to see, and to measure.

5. *chip control studies*

From work carried out so far, it is evident that in the speed range up to 2,000 f.p.m. chip control is not too difficult where the speed and depth of cut are reasonable. The proportions established over the years for chip grooves in carbide cutting edges are in general applicable at these speeds.

The position in the speed range above 2,000 f.p.m. is by no means clear, since rapid cratering of the carbide chipbreaker takes place when the chip "streams" dangerously. At a speed of 3,000 f.p.m. the chip is projected approximately 15 ft. upwards and outwards from the cutting edge, which is, of course, highly dangerous. Little warning of this occurrence is given and the ribbon of swarf is very hot and sometimes in an extreme plastic condition.

However, research in this direction is not urgent, as the problem is unlikely to arise until machine tools are generally capable of these speeds on small diameters.

MILLING

Test billets in the same range of materials as employed for turning tests are used in a standard size of 6 in. × 12 in. × 36 in.

To a large extent, the machine is being employed to evaluate new and experimental grades of carbide which have been specifically designed to overcome the severe problems presented by the interrupted thermal and mechanical shock when milling steel at high feed rates.

Although the Müller lathe can readily be adapted for milling, the Heller provides a means of testing oxides also, particularly multi-tooth face mills designed for high feed rates.

Using cutter bodies of up to 12 in. diameter, surface speeds of 3,000 f.p.m. have been achieved on steel. There is, of course, much to be learnt before oxides can be seriously considered for production milling, as experiments have yet to show the relative load-carrying capacity of oxide tips under deliberately severe interrupted thermal and mechanical shock conditions. There is, therefore, at this stage little information that can be offered concerning milling, as we are only too aware of the difference in conditions provided by our milling machine and those generally available for industry.

FIELD TESTS

Under the supervision of our development engineers, certain tests on a wide variety of materials are being conducted on users' machines of orthodox design. In these cases, normal production components are being machined and users have been most co-operative in placing such facilities at our disposal. It has been necessary to limit tests to the types of materials and operations on which we seek information and also to examine carefully the machine tools proposed for use in the tests.

Among materials being tested are chromium cast irons, stainless steels and special high tensile steels as used in the aircraft industry.

It is too early at this stage to assess the information now being sought in these experiments but it is proposed to make these reports available at a later date, if the users concerned can agree to their publication.

GRINDING FOR RESERVICING

We have found a wide difference in the resistance of various oxides to grinding, no doubt because the many oxides at present under development in the world vary widely in terms of their hardness.

From experiments which we have carried out the following recommendations may be made :-

1. It is essential to grind wet. In all cases an excess of coolant should be present, preferably applied to the wheel centrifugally. Dry grinding causes burning of resinoid bonded wheels, which in turn causes chipping of the cutting edges. With metal bonded wheels, dry grinding promotes the generation of excessive heat and this will also cause chipping of the oxide.
2. Resinoid bonded wheels cut faster and freer than metal bonded wheels.
3. Gravity feed will provide sharp edges even when grinding away from the cutting edge as well as cutting towards the edge. Fixed feed grinding will also give chip-free edges, provided that the relative movement between the wheel and the work is slow enough to allow sparking out to take place.
4. Where a slower rate of stock removal can be acepted, metal bonded wheels may be used with equal success provided adequate dressing is maintained and pressures kept to a minimum.

In our Diamond Wheel Department we employ a standard test rig designed to check the stock removal rates, both initial and sustained, of various types of wheel. This apparatus employs test pieces ½ in. square which are pressed on to the oscillating wheel under a gravity load of 5 lb.

A resinoid bonded wheel, reference D200-50-B4-1/16, removed the following amount of material in inches per minute from the test piece :-

Wimet 'N'	... ...	.025 in.
Wickman Oxide	...	.050 in.
Oxide 'A'	... ...	.090 in.

Under the same conditions a metal bonded 120/160 diamond wheel removed .018 in. in the same time and was reasonably consistent on all three materials.

future possibilities and machine tool requirements

There is no doubt that sintered oxides provide a useful addition to the present range of tool materials. Coupled with the improvements continually being made in sintered carbides, there is now an urgent need for progress in machine tool design.

Although it is about 30 years ago since tungsten carbides were first introduced, it is remarkable that there are still machine tools in existence older than the origin of tungsten carbides and on which attempts are being made to obtain higher production with carbide tools.

If a machine tool is capable of full exploitation of the power input by the use of high speed steel, the gain in using carbide is in terms of cutting edge life only where a reduction might be made in the "down time" of the tooling. Under this condition of full exploitation of the power input, the machine can remove no more metal with one tool than with another. Similarly, discrimination is necessary when applying oxides to machine tools which are already fully exploited by carbide.

The bulk of experimental work done so far in the world with oxides has been carried out on machines not of the latest design. It should be borne in mind that many of these machines have been used at low spindle speeds and the high surface speed has been obtained when machining very large diameter billets. Results achieved in this way can be misleading, since the ratio of diameter to length of the workpiece is one which is rarely encountered in industry, and the effective front clearance of a tool is different when turning a small diameter as opposed to a large diameter.

It is only in recent years that machine tools of advanced design have occasionally become available. On these machines, which are few in number, it is possible to set metal removal rates greater than can be achieved with carbides in their present state of development. Work, however, is well in hand to provide carbides capable of matching these machine tools.

From present knowledge the field of application for oxides appears to be in the speed ranges beyond those normally catered for by carbides at the present time, the cutting loads at these higher speeds not necessarily exceeding those within the capacity of carbides. As higher cutting speeds are made possible by the use of alternative cutting materials, not necessarily either carbides or oxides, so the power required to remove metal faster imposes conditions which the machine tool designer will require to meet.

The provision of automatic constant speed and feed control in such machines is highly desirable. Problems will also be presented in cooling the workpiece and in the method of application of such coolant. If liquid is used, at high rotational speeds considerable spray is developed, which means that the machine must be completely shrouded. The coolant must be introduced carefully to ensure that it does have full effect by being delivered in the correct place. In our opinion, the very haphazard flood cooling in general use today would be utterly useless.

A further problem will be undoubtedly that of swarf disposal. This is a problem which is already creating limitations to the production rates of modern machine tools employing carbides, and the provision of swarf conveyors is not necessarily the complete answer. One can even visualise greater capital cost being involved in the equipment for evacuation of swarf in a production unit than the cost involved in the metal removal unit itself.

A great deal of work has already been done in the achievement of high spindle speeds with bearings capable of long life and adequately lubricated under such circumstances, but the advanced features incorporated in the Wickman research equipment described earlier will require to be commonplace before the full scope of exploitation for sintered oxides can be determined for industry.

acknowledgments

The authors wish to thank Hard Metal Tools Limited for permission to use material from Dr. E. M. Trent's Paper "Developments in Turning and Single-point Tools, with particular reference to Developments in Cutting-tool Materials", presented to the Conference on Technology of Engineering Manufacture arranged by The Institution of Mechanical Engineers, in London, 25th - 27th March, 1958.

They also thank the Carboloy Department of the General Electric Company, of Detroit, U.S.A., and Krupp Widia-Fabrik, of Essen, for the provision of material included in the review of world progress.

Finally, they wish to thank Messrs. Firth-Brown Tools Limited for information and assistance received.

(for references, please see overleaf)

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The authors also wish to acknowledge reference to and the use of illustrations and material from the following sources :-

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carbide and ceramic tools in the finish turning of steel

a comparative investigation

by Vladimir Šolaja, Dipl.-Ing., A.M.I.Mech.E.

From the information available on ceramic tools, it seems that they offer definite advantages over the "classic" tool materials. However, owing to some unfavourable physical characteristics, for the time being they are recommended mainly for lighter cuts. The criteria in finishing cuts are surface finish, dimensional accuracy and residual stresses in the surface layers — of these the first two appear to be better with ceramic tools, while the residual stresses are slightly higher. Again, wear is less. This Paper is an account of the work so far completed by the author.

THE world's technical press over the last few years covers much information on ceramic tools. Although the field is expanding rapidly, so far there seems to be no satisfactory comparative analysis of the results obtained in various countries, though it appears justifiable to suppose that in turning steel and some other materials — especially with lighter cuts — ceramic tools compare favourably with the "classic" tool materials.

Depending on the operation involved, various cutting factors determine the economical and technical aspects of machining. In finish turning they are surface finish generated, dimensional accuracy and the residual stresses in surface layers. From many information on ceramic tools [e.g. see the bibliography compiled by Brewer (1957a) *, or a recent review by the author (Šolaja 1957b)], a few sources may illustrate the main points.

Spear, Robinson and Wolfe (1952) compare surface finish and depth of deformed layer in fine turning various metals with high-speed steel, carbide and ceramic tools. For mild steel, surface finish is best for ceramic tools, the depth of deformed layer being larger than for carbide, but less than for high-speed steel tools. Similar views are expressed by Zhikharev (1956); in addition, he showed that a better dimensional accuracy of the workpieces is achieved with ceramic tools.

According to Shaw and Smith (1957), the difference of surface finish obtained with carbide and ceramic tools is due solely to the formation of the built-up edge and its variability in the course of cutting.

Mr. Šolaja, who is Lecturer in the Faculty of Mechanical Engineering at the University of Belgrade, has for the past two years been engaged on research at the Wolverhampton and Staffordshire College of Technology.

* An alphabetical list of references is given at the end of the Paper.

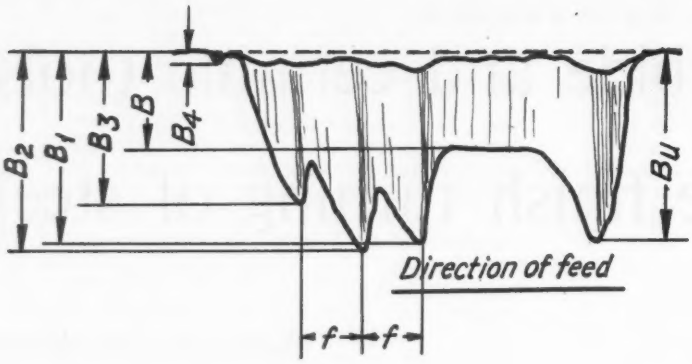

Fig. 1. Clearance face with the typical pattern of wear in finish turning of steel.

It appears that, owing to the great influence of chance phenomena, a more systematic research along the proposed lines is needed; on the other hand, they do not take into account the influence of wear.

In an extensive research programme, Tamaru and Shiraishi (1956) made an attempt to classify the types of tool failure. Their conclusion about the inferior surface finish obtained with ceramic tools contradicts the rest of the information available.

Among many similar works, Albrecht (1957) reports that the variation of surface finish in prolonged turning 0.45% carbon steel with ceramic tools was within 28 and 32 μin. (the limits appear to be exceptionally close), whereas Brewer (1957) asserts that the surface finish is only slightly superior to that obtained with carbide tools.

From the point of view of wear, the study by Schmidt, Ham, Phillips and Wilson (1956) is of importance. From the fact that the width of wear-land at the clearance face with ceramic tools increases irregularly, they conclude that the crumbling away of the small particles is the main cause for wear. This view is supported by Nadeinskaya (1956). In addition, by using radioactive tools, she noticed that the greater part of loose wear-particles is lost, whereas with carbide tools most of these particles are deposited on the machined surface or on the chip.

Thus, according to the information so far available, ceramic tools seem to have some advantages over the "classic" tool materials in finish turning of steel: surface finish and dimensional accuracy are superior, but residual stresses are slightly higher.

The object of the work attempted by the author was to connect the wear-phenomena in finish turning with the first of the criteria in such machining — the surface finish generated. Further on in the Paper, the main results are reviewed.

the results of the author's work

In a systematic research programme on finish turning with carbide tools, which started at the

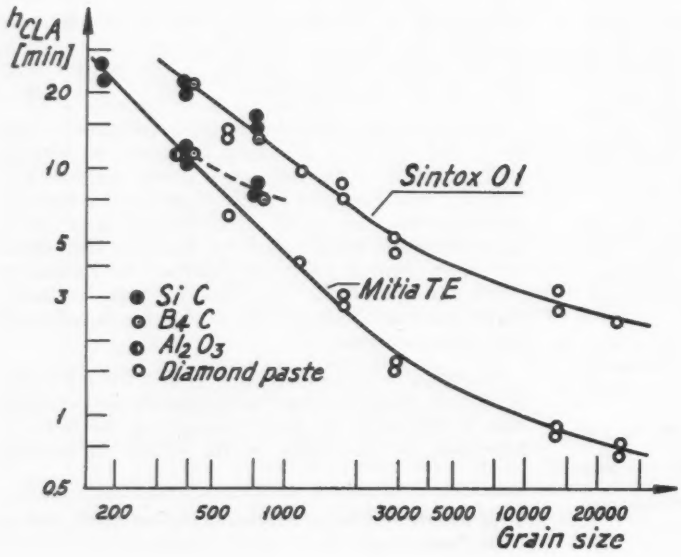

Fig. 2. Finishes obtained when lapping ceramic Sintox 01 and carbide Mitia TE tips with various lapping media.

Faculty of Mechanical Engineering, University of Belgrade, Yugoslavia (1957a), and continued since at the Wolverhampton and Staffordshire College of Technology, Wolverhampton (Šolaja 1957d, Šolaja 1958b), the author reached conclusions which may be summarised as follows:

(i) The surface finish obtained in turning steel with a "sharp" carbide-tipped tool is only a hypothetical case, because, owing to the wear, the tool-form as reproduced on the machined surface changes from the very start of cutting. In finish turning concentrated wear in the form of grooves is usually present, the grooves being localised at the boundaries of the contact areas between the tool and the chip, viz. the work-piece.

(ii) Typical wear-pattern on the clearance face of a worn carbide-tool may be seen in Fig. 1, and in microphotographs further on in the Paper. The symbols adopted by the author are used. In addition to the groove B_u under the leading edge, which has no direct influence on roughness, groove B_1 forms at the intersection of the trailing edge and the surface generated in the previous revolution. This groove moves in the direction of tool-feed as its length increases. The crests of feed marks may reach the trailing edge at a distance from the first groove equal to the tool-feed, thus initiating a second groove; eventually, a number of grooves may develop in like manner.

(iii) The difference (B_1 - B) was shown to be directly related to the maximum roughness h_{max}, and it seems to be possible to find an empirical relationship for the centre-line average roughness h_{CLA} also. A number of technological consequences have been examined already.

(iv) Grooving appears to be a very complex phenomenon, differing from the phenomena which occur at the remaining parts of the interface, and a number of possible causes have been listed. However, it appears that fatigue, in close relation with the others, is largely responsible for regulating groove-formation.

Taking into account that ceramic and carbide tools differ widely, it would be of considerable interest, both practical and theoretical, to examine systematically the behaviour of the two tool materials. An interim report from this work has been published already in Yugoslavia (Šolaja 1958a), and those results together with some new findings are reviewed under two headings:

1. experimental techniques; and
2. experimental results.

1. *experimental techniques*

The dimensions of both carbide and ceramic tips were approximately in. × $\frac{3}{4}$ in. + $\frac{3}{16}$ in. and the tips were mechanically held in specially designed toolholders. The clearance face along the $\frac{3}{4}$ in. side was given a rough form by grinding, final shape being obtained under a microscope, against a precision graticule, by hand-polishing with diamond paste, grain size approximately 3 000. Tool geometry throughout the test was: back-rake angle $a = 0°$, back-clearance angle $\gamma = 8°$, included angle $\Sigma = 80°$, tool-nose radius r = 0.020 and 0.030 in. It was essential to give the sharp edge thus produced a chamfer of 45°, and of the width of approximately 0.0002 in.

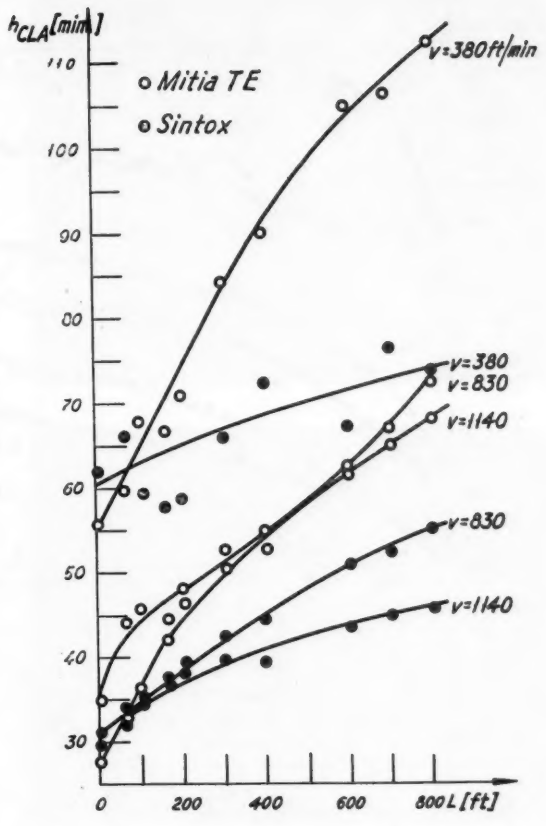

Fig. 3. Mean values of surface finish in turning 0.25%-carbon steel with ceramic Sintox 01 and carbide Mitia TE tipped tools in preliminary experiments.

The optimum surface finish of tool-faces has been widely discussed in the technical press. The importance of the subject of surface finish of these materials in other fields, e.g. guides in textile machinery, was thought to warrant some investigation. Therefore, some results achieved by hand-lapping ceramic-tips Sintox 01, and carbide-tips Mitia TE with various lapping media are given in Fig. 2. It may be seen that with all the lapping media, surface finish measured on a Talysurf Model 3 Surface Analyser is inferior with ceramic material.

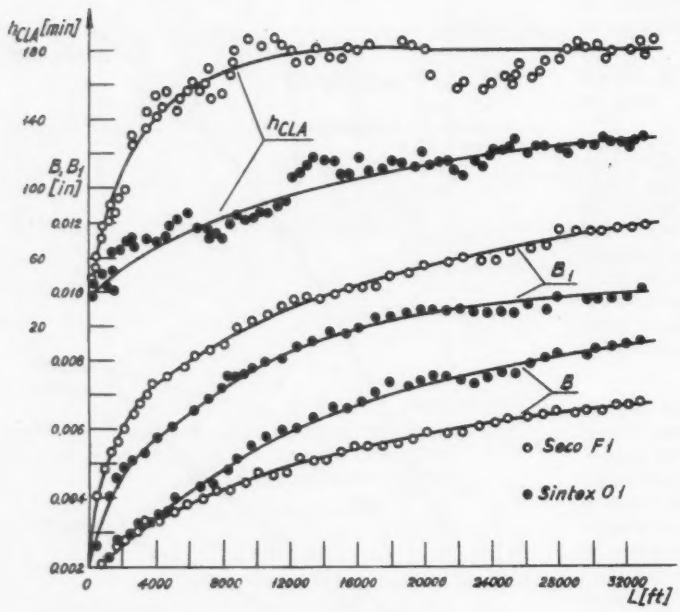

Fig. 4. Magnitudes of tool-wear and surface finish as functions of the cutting length L in turning 0.25%-carbon steel with ceramic Sintox 01 and carbide Seco F1 tipped tools. r = 0.030 in.; = 0°; γ = 8°; f = 0.004 in./rev.; t = 0.005 in.; v = 900 f.p.m.

The machining tests and the measurements of wear-magnitudes and of surface finish were performed in the same manner as described recently (Šolaja 1958c). Most of the experiments were carried out with ceramic tips Sintox 01 and carbide tips Mitia TE and Seco F1 * on the bars of 0.25%- and 0.38%-carbon steel and additional tests with some other tool-grades and on other varieties of steel.

In a few prolonged tests it was shown that usually, after a length of cutting of L = 6,000 to 7,000 ft., the wear and surface finish stabilise and, therefore, in the majority of the tests the length of cutting was approximately L ≃ 8,500 ft.

According to some previous reports [e.g. Isaev, Zorev and Kuchma (1952)], the scatter of the wear-magnitudes with ceramic tools is considerably larger than with carbide tools and, consequently, special care had to be exercised in controlling the conditions when repeating experiments. In this manner the scatter was held within reasonable limits (in a band usually less than ± 10% for wear, ± 20% for surface finish).

2. *experimental results*

The results of preliminary tests (Šolaja 1957c) are given in Fig. 3, where ceramic tools show a decrease of roughness. The experiments at this stage did not justify any far-reaching conclusions on the relative performance, but they proved the interesting new finding that *in spite of the differences between the two, the same phenomenon of concentrated wear in finish turning of steel occurs with both tool-materials. The quantitative discrepancies in the intensity of this phenomenon are responsible for the differences of the surface finish obtained, the same analysis as for the case of carbide tools* (Šolaja 1958c) *being applicable to ceramic tools also.*

The importance of this finding can be easily appreciated from Figs. 4-8 which illustrate an experiment on prolonged turning 0.25%-carbon steel with Seco F 1 and Sintox 0 1 tools. In Fig. 4, the functions B_1, B, h_{CLA} = L(ft) are drawn (curves B_2, B_3, etc., being omitted), showing clearly that B is slightly larger, B_1 smaller with ceramic tools, and the difference (B_1 - B) being smaller, surface finish is improved. This is also apparent from the micro-photographs in Figs. 5 and 6 corresponding to the various stages of wear of the clearance faces, as well as from Fig. 7, where a few pen records are reproduced. The final appearance of the rake faces may be seen in Fig. 8.

Qualitatively similar observations can be made on the grounds of the experiments conducted under identical conditions except for the tool-feed. These results are shown in Figs. 9 and 10. Although the concentrated wear is clearer with carbide tools [partly due to the possible effect of minute crumbling and/or adhering of workpiece-material with ceramic tools as presumed by Nadeinskaya (1956)], the grooves are distinctive with this small feed also.

A different situation arises with 0.38%-carbon steel, and in Fig. 11 the wear magnitudes and the surface finish for the tool Sintox 0 1 are shown. On comparison with Fig. 4, larger wear and increased roughness may be observed; under the same conditions, the results with a carbide tool Seco F 1 are only slightly inferior.

* Chemical composition of carbide tips is: WC 75% and 70%, TiC 17.5% and 25%, Co 7.5% and 5% respectively.

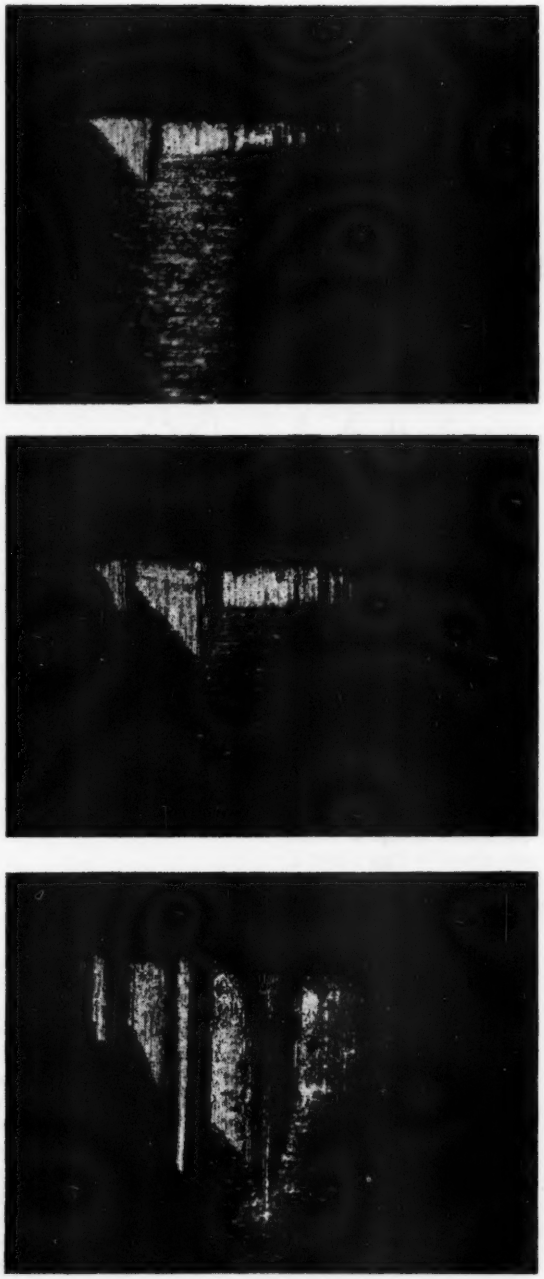

Fig. 5. Clearance face of the carbide Seco F 1 tipped tool from Fig. 4 in various stages of the same experiment. The microphotographs correspond to L = 350, 1,500 and 32,000 ft. Direction of cutting from left to right, magnification 180 X.

Fig. 6. Clearance face of the ceramic Sintox 01 tipped tool from Fig. 4 in various stages of the same experiment. The microphotographs correspond to L = 350, 1,500 and 32,000 ft. Direction of cutting from left to right, magnification 180 X.

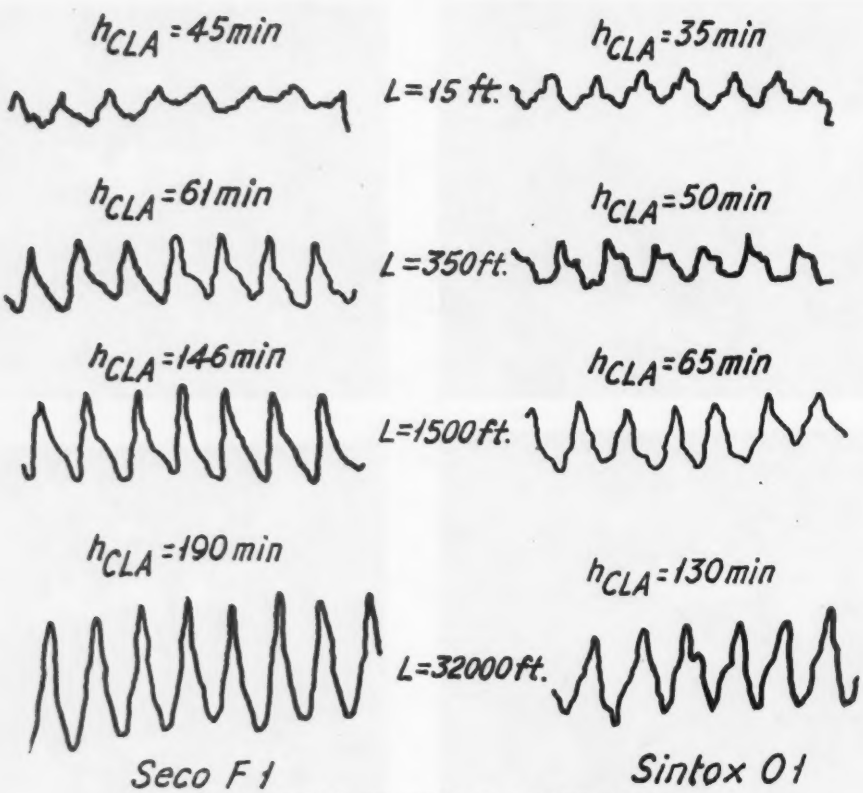

Fig. 7. Characteristic pen records on a Talysurf Model 3-Surface Analyser from experiments shown in Fig. 4. These correspond to the microphotographs shown in Figs. 5 and 6, and to the start of cutting (L ≃ 15 ft.). Direction of cutting from right to left, horizontal/vertical magnification 2000/100 X.

The influence of tool-feed on the wear-magnitudes and surface finish for the two tool-materials in finish turning 0.38%-carbon steel can be appreciated from Fig. 12. The straight lines in the diagram show only qualitative trends — further systematic research being necessary for definite conclusions.

A few experiments by changing cutting speed and depth of cutting were carried out. The first showed similar qualitative trends to those given in Fig. 3, and the depth of cut, when increased by a factor of up to 5, did not seem to affect the wear on the clearance face to any appreciable extent.

Interesting observations were made when using two more grades of ceramic tools (Sintox 0 3 and Secoramic), and three varieties of alloy steel. From a restricted number of tests it may be presumed that Sintox 0 3 is more wear-resistant than Sintox 0 1 or Secoramic, the last having an increased tendency towards edge-crumbling. In cutting alloy steel, a tendency for the difference (B_1 - B) to decrease exists, and consequently, although the magnitude of wear has been greater, improvement of surface finish has been achieved. The disappearance in some cases of concentrated wear, resulting in only a slight increase of initial roughness, was noticed both with carbide tools at high cutting speed (Šolaja 1958b) and ceramic tools at normal speeds. An example is given in Figs. 13 and 14. As is apparent from the microphotograph of the rake face, owing to this form of wear the initial tool-nose radius actually increases (i.e. the nose "flattens"), instead of decreasing as had been noticed in the case when concentrated wear takes place (Šolaja 1957a). However, the surface finish does not improve as could have been expected, because of a short groove, noticeable on the right side of both faces in Fig. 14, which appears to make the surface finish deteriorate. Under the same conditions the results with a carbide tool Mitia TE were quite different: the surface finish at the end of cutting was $h_{CLA} \simeq 160$ μin., the wear magnitudes being: B = 0.0039 in., B_1 = 0.0118 in. and B_2 = 0.0094 in.

It has to be pointed out that in most of the experiments reviewed, the groove under the leading edge B_u with ceramic tools was longer than the grooves under the trailing edge, and in a majority of cases its length was also greater than for carbide tools. This observation does not affect surface finish generated, but it may be of interest when economy of cutting (i.e. tool-life) is considered.

Fig. 8. Rake faces of a carbide Seco F 1 (above) and ceramic Sintox 01 (below) tipped tool corresponding to Figs. 5 and 6. Direction of cutting from right to left, magnification 180 X.

Fig. 10. Clearance face of a carbide Seco F 1 (above) and ceramic Sintox 01 (below) tipped tool from Fig. 9. Direction of cutting from left to right, magnification 180 X.

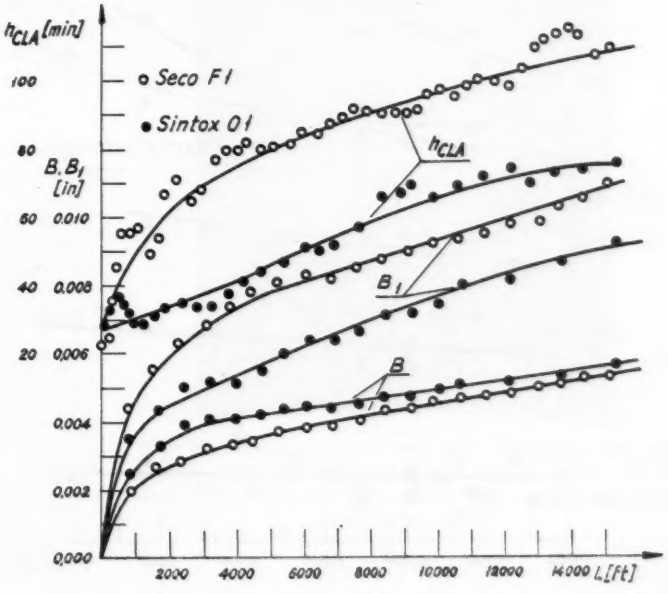

Fig. 9 (right). Magnitudes of tool-wear and surface finish in turning 0.25%-carbon steel with ceramic Sintox 01 and carbide Seco F 1 tipped tools. Same conditions as in Fig. 4, except for feed f = 0.0021 in./rev.

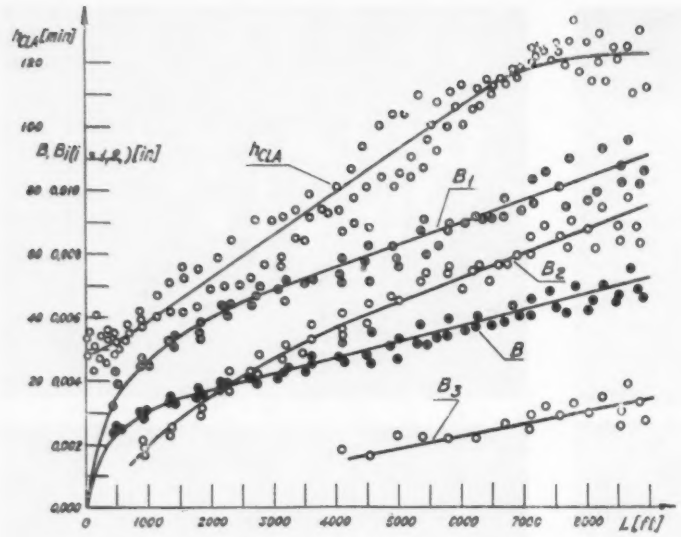

Fig. 11. Magnitudes of tool-wear and surface finish in turning 0.38%-carbon steel with ceramic Sintox 01 tipped tool. Same conditions as in Fig. 4.

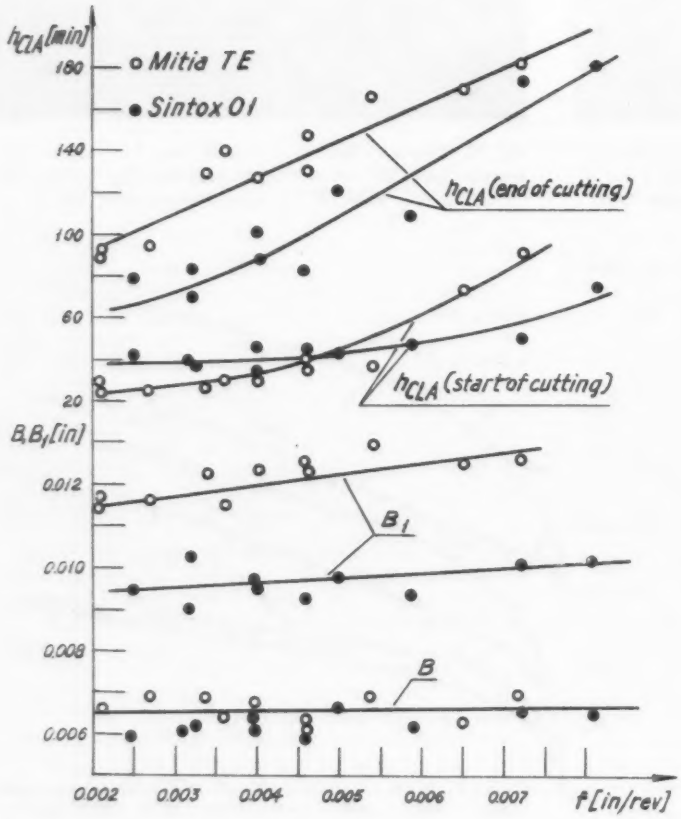

Fig. 12. Magnitudes of tool-wear and surface finish as functions of tool-feed in turning 0.38%-carbon steel with ceramic Sintox 01 and carbide Mitia TE tipped tools. Same conditions as in Fig. 4, except for feed f = 0.0021 - 0.0082 in./rev.

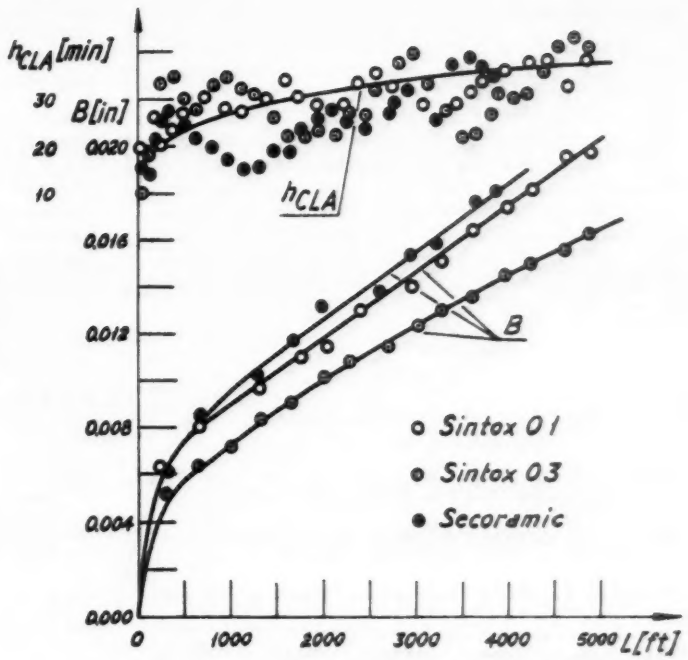

Fig. 13 Width of wear-land and surface finish in turning 1%-C-Cr-alloy steel (EN.31) with ceramic Sintox 01, Sintox 03 and Secoramic tipped tools. Same conditions as in Fig. 4, except for cutting speed V $\simeq$ 550 ft./min.

conclusions

The research programme reviewed in this Paper enables the following conclusions to be drawn at this stage :

1. In spite of the fact that the chemical, physical and mechanical characteristics of ceramic tools differ considerably from those of carbide tools, the interesting phenomenon of concentrated tool-wear in finish turning of steel (i.e. the formation of grooves at the boundaries of the interfaces clearance face/workpiece and rake face/chip) is a characteristic phenomenon in both cases.

2. As shown earlier by the author, the wear-magnitudes — in the first place the difference (B_1 - B) — are directly related to the surface finish obtained in finish turning. In all cases which have been examined, this difference was smaller with ceramic tools and, therefore, a better surface finish was to be expected. This assumption was confirmed in the experiments.

3. It has been shown that the wear, and as a consequence the surface finish also, are largely affected by the workpiece material and by the cutting conditions. Much remains to be done to analyse systematically the influence of the variables encountered in machining, but it was proved that, within the cutting conditions applied in these experiments, wear under the trailing edge of ceramic tools was usually less than for carbide tools.

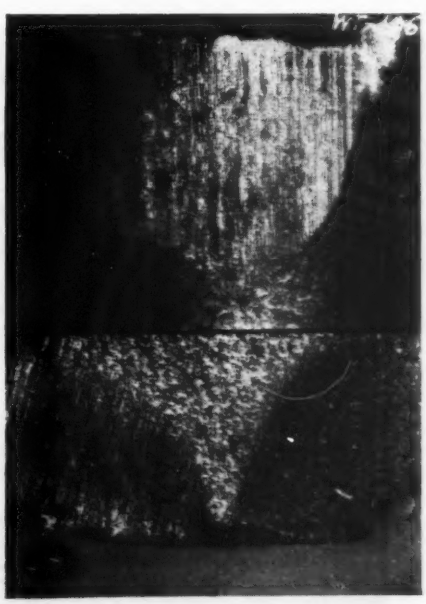

Fig. 14. Clearance (above) and rake (below) face of the ceramic Secoramic tipped tool from Fig. 13 at the end of experiment. Direction of cutting from right to left, magnification 100 X.

acknowledgments

Acknowledgments are made to Prof. P. Stanković, Dr.-Ing., Faculty of Mechanical Engineering, University of Belgrade, Yugoslavia; and to Mr. M. G. Page, A.M.I.Mech.E., A.M.I.Prod.E., Head of the Department of Production Engineering and Management, Wolverhampton and Staffordshire College of Technology, Wolverhampton, for encouragement given and facilities provided. The author's special gratitude is due to Mr. H. L. Hughes, B.Sc., for much help with the English version of the Paper, to Mr. F. Wray, Grad.I.Prod.E., for his assistance in the practical work entailed, to the laboratory staff of the above institutions for all the help in conducting the experiments, and to the following firms for generously providing items needed in this research programme:

Lodge Plugs Ltd., Rugby, and English Steel Tool Corporation Ltd., Manchester (ceramic tips Sintox and 0.38%-carbon steel); Fagersta Bruks Aktiebolag, Fagersta, Sweden (carbide tips Seco and ceramic tips Secoramic); Fisher Bearings Co. Ltd., Wolverhampton, and J. Brockhouse & Co. Ltd., Wolverhampton (alloy steel); and Engis Ltd., London (diamond paste).

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production problems associated with industrial atomic energy

A Paper presented to The Institution of Production Engineers at Wolverhampton, in December, 1957

by Dr. J. E. Littlechild

Dr. Littlechild, who is Technical Officer in charge of chemical productions at Operations Branch Headquarters of the U.K. Atomic Energy Authority, was educated at Boston Grammar School, Lincolnshire; and University College, London. He graduated in chemistry immediately prior to World War II, during which he served in the Royal Army Ordnance Corps.

He returned to University work in 1946, at the University of Sheffield, in the Department of Fuel Technology of the Engineering Faculty, where he was appointed the first Coke Research Fellow of the British Coke Research Association. Between 1948 and 1950, he was a Lecturer in Fuel Technology at Sheffield, and in 1950 was awarded the degree of Ph.D.

In 1950, he joined the National Coal Board at their Central Research Establishment, where he was particularly concerned in the development of processes for the production of smokeless fuels, and assigned several patents to the National Coal Board on the application of fluidised bed processes to the treatment of fine coal.

Dr. Littlechild joined the Operations Branch of the U.K.A.E.A. in 1955, and has specialised in work on the chemical processing of uranium fuels and the production of nuclear reactor fuel elements.

nuclear power production

The largest programme of capital investment ever faced by the U.K. in peace-time is just beginning — I refer to the programme for construction of atomic power stations. First announced in February, 1955, a White Paper described the programme for construction of nuclear power stations designed first and foremost for electricity generation. This programme suggested, optimistically, that electricity generating capacity from nuclear sources might total 1,500 - 2,000 MW by 1965.

Since then, the first two Calder Hall power-producing reactors have been completed and are feeding electricity into the grid. Progress on the design of the carbon-dioxide cooled reactor has been well maintained, and we now know how to design and build a much bigger size of reactor station than was foreseen in 1955. The White Paper estimated that the first Commercial Stations would be of 100 - 150 MW capacity, but tenders already have been placed for the construction of a 275 MW station at Berkeley, Gloucestershire, a 300 MW one at Bradwell, Essex, and the stations at Hunterston, Ayrshire, and Hinkley Point, Somerset, are planned to have capacities of 320 MW and 500 MW respectively. Plans for other large stations were recently announced for Trawsfynydd (500 MW output) and an even larger one at Edern (800 - 1,000 MW).

Programmed nuclear capacity is now estimated as being 5,000 - 6,000 MW in operation equivalent to 28% of total U.K. electrical output with a saving estimated at about 18m tons of coal (40% of total by early 1970's). The total capital investment needed for the electricity programme is estimated at £3,350

million. This is about £750 million more than if all the new capacity were conventional plant and illustrates one of the peculiarities of nuclear power, which is the very high capital investment needed and the low operating cost, by contrast to the conventional fuel power stations. The charge of uranium metal fuel in each reactor is a very large capital item (260 tons uranium in the two Calder Hall reactors — 500 tons in two of the C.E.A. designs), but this charge requires replacement at very infrequent intervals and even then can be re-processed and largely re-used.

Although the "nuclear power stations" will be designed by "industrial consortia" in collaboration with the U.K.A.E.A., and owned and operated by the electricity authorities, the Atomic Energy Authority have several particular responsibilities. The U.K.A.E.A. must procure and import uranium ore. They must manufacture fuel elements for sale to the electricity authorities and after use reprocess them for separation of uranium, plutonium and the highly dangerous radioactive fission products. It can be confidently expected that from the early 1960's onwards, the probable price of nuclear power will fall to less than the price of power from fossil fuels. The advantages of cheap electrical power to industry are obviously very great.

production of nuclear energy

The great virtue of atomic energy is, of course, the production of very large amounts of energy from very small quantities of fuel. As a simple comparison 1 lb. atomic fuel elements (which are very heavy — size of a matchbox) = 1,000 tons of coal for energy production.

Now an atomic power station is, in reality, a very simple thing — it consists basically of a pile (which is the equivalent of a furnace in conventional power plant) a steam generator and power turbine.

Atomic energy is produced from the fission of large atoms, e.g. U and Pu.

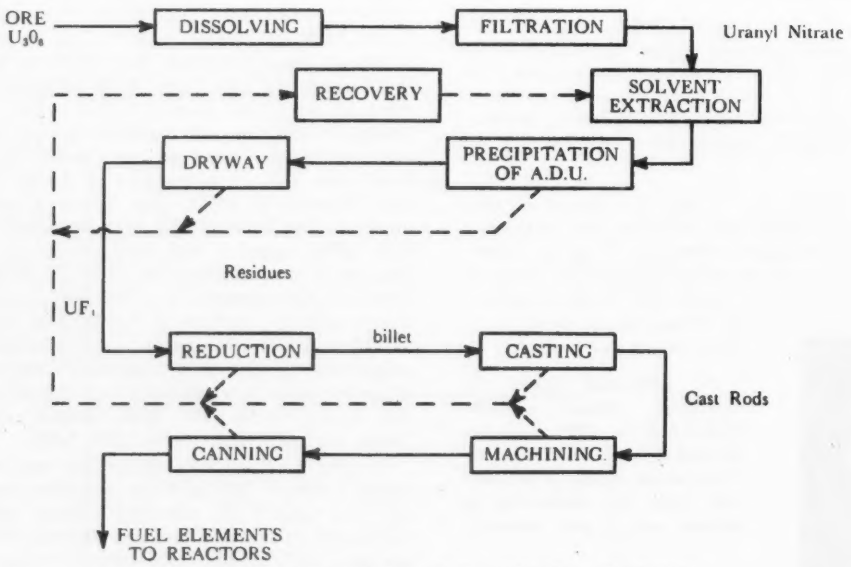
thermal neutron fission is the simplest type of atomic breakdown.

The only naturally-occurring fissile element is the U^{235} isotope of U and natural U contains 1 atom U^{235} per 140 atoms U^{238} (0.7%).

The slow neutron fission of U^{235} enables a controlled chain reaction to be maintained, i.e. an operating reactor. This is because neutrons when emitted are fast and with 140 atoms U^{238} to 1 atom U^{235}, the probability is that they will strike U^{238} atoms and be absorbed.

By slowing down neutrons, the probability of striking U^{235} atoms is increased, so moderators are used in which the neutrons strike and share their energy with other suitable (i.e. non-absorbing) atoms. The neutrons are slowed to velocities corresponding with the moderator temperature and so are called thermal neutrons — a slow reactor, therefore, is called a thermal reactor.

During thermal neutron fission plutonium is produced and the first piles built in U.S.A. and Great Britain were constructed to produce Pu, the heat generated being wasted. The plutonium is separated out by a very lengthy and costly process of chemical separation. Handling and chemical treatment of the irradiated fuel elements is complicated by the fact that they are highly radioactive owing mainly to the presence of radioactive fission products. The fission



Diagrammatic representation of the extraction of uranium

products moreover slow down the chain reaction, as they are neutron absorbers and will eventually make the reaction die out.

the extraction of uranium and manufacture of cartridges

The purpose of this process is to extract from ores or concentrates uranium with a low content of neutron absorbing elements and others which may adversely affect the metallurgical properties during casting, machining and irradiation in the reactor. Additionally, the impurities must not cause difficulty in the subsequent processing of the irradiated fuel. Uranium is not manufactured by smelting, but by dissolution in acid, followed by batch-wise processes of solvent extraction and chemical reaction.

The ore may be assumed to be received in the form of essential U_3O_8 which, after crushing and slurrying, is fed with nitric acid at a controlled rate to the dissolver. The resultant uranyl nitrate solution is freed from insoluble matter by filtering through a plate and frame press.

Purification is carried out by a continuous solvent extraction process in which a controlled feed of crude uranyl nitrate solution is fed into contact boxes, the bulk of the uranium passing into the solvent, the impurities remaining in the aqueous phase. The solvent phase is heated and the uranium back extracted into water. From this solution ammonium diuranate is precipitated by treatment with ammonia and filtered under vacuum on a Nutsch filter.

In the dryway process, the partly dried diuranate is loaded on to graphite trays which when stacked in the reactor, allow the reactant gases to pass uwards from tray to tray and across the surface of the contained solid.

The calcination reaction produces uranium trioxide, water and ammonia ; in the next stage uranium dioxide is produced and, finally, the tetrafluoride is formed as a result of treatment with anhydrous hydrofluoric acid. Both the temperature and conversion times are quite critical at all stages of this process, the physical form of the tetrafluoride produced being important to the next operation.

The metal reduction charge consists of a mixture of magnesium raspings and tetrafluoride and the reaction is carried out in a pressure vessel lined with graphite. The reaction is strongly exothermic and is initiated by heat. A very good separation of metal and slag is obtained and after the reactor contents have cooled down, a solid metal billet of some hundreds of kilograms weight is separated from the slag.

This plant creates many residual arisings of uranium in the form of mother liquors, slags, swarf, crucible linings, etc. The general principle employed for the recovery of uranium is to recover by means of precipitation, in some cases preceded by an acid leach, the resultant precipitates being dissolved in acid and recycled into the purification stage.

The fuel elements used in our present reactors are principally made from metallic uranium. As a metal this is not a particularly attractive material to fabricate.

properties of uranium metal

Atomic No. : 92
Atomic Weight : 238.1
Solid phases : 3 (α, β, γ)
Density : 19.0 g/c.c. (2.4 times that of steel)
Melting Point : 1,133°C
Radioactivity : (Natural U) — 6.5×10^{-7} α — curies per gramme

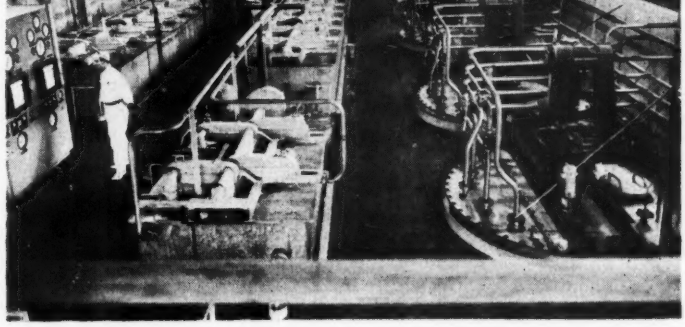


Fig. 1.
Uranium purification at Springfields Works

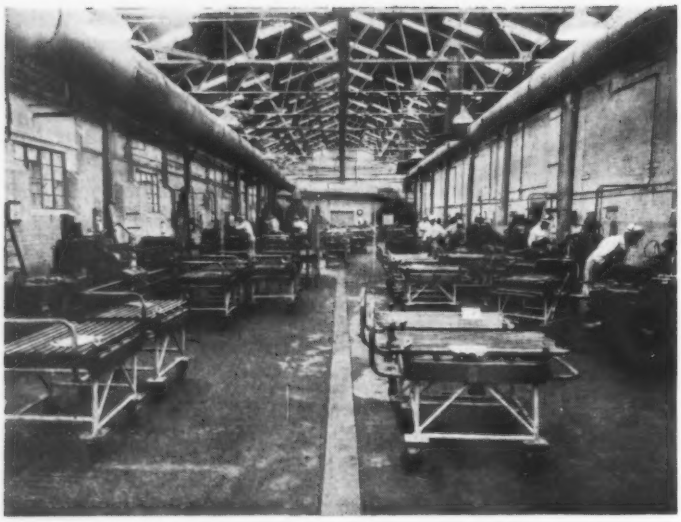


Fig. 2. Uranium machine shop

In visual appearance, a bar of freshly-machined uranium closely resembles steel. The difference is easily detected, however, on picking up the bar — it weighs almost 2.5 times as much as a similar steel bar.

Indeed, it may be said that any resemblance between uranium and many of the common metals ceases with visual appearance. In addition to being slightly radioactive (it emits α particles — i.e. helium nuclei), uranium is extremely active chemically. It reacts with the common gases oxygen, nitrogen and hydrogen, and hence all melting operations must be carried out in vacuo or under argon. The material of the crucible for containing the molten metal also raises problems, since molten uranium reacts chemically with many of the more common refractory materials. High purity graphite has proved the most convenient material for crucibles and moulds; although it is dissolved slightly by molten uranium, carbon is one of the least harmful impurities in uranium from the nuclear point of view.

Uranium is a relatively weak metal, and is only moderately ductile at room temperature. Its strength falls very rapidly with increasing temperature — from about 53,000 p.s.i. at room temperature to about 27,000 p.s.i. at 150°C. It can be fabricated tolerably well by conventional procedures — forging, rolling, extrusion, etc., though cold working must be limited to small reductions, and in hot working, protection from the atmosphere is essential.

In the U.K.A.E.A., uranium bars for fuel elements are cast and then machined to finished dimensions. Machining must be carried out using heavy cuts and high speeds; in addition, a plentiful supply of lubricant must be provided which in addition to its normal function serves to minimise the fire-risk. Orthodox types of centreless bar turner are used for the purpose, and give very satisfactory results. All scrap in the form of turnings, cropped ends, etc., must be carefully preserved; and is chemically cleaned before being returned to the melting furnaces.

The purity of uranium metal for nuclear applications is extremely important. Apart from carbon and small additions of certain elements made for a specific purpose, the levels of most impurities cannot be allowed to exceed a few parts per million. Certain elements such as boron and cadmium are objectionable if they exceed a few tenths of a part per million. The importance of strict control over all operations and over "housekeeping" generally is, therefore, obvious.

fuel element production

The method generally employed for uranium fuel element production in this country comprises a sequence of casting, machining and heat treatment. Casting of the uranium into bars is carried out from a vacuum casting furnace of fairly conventional type, charged with approximately 400 lb. of uranium billet at each melt. Machining is kept to the minimum consistent with the production of a normal engineered bar, with only those small modifications needed for its special function and to simplify canning methods.

It is known that on heating and cooling of uranium metal, quite considerable thermal stresses are set up owing to the unusual crystal structure of uranium which has little symmetry. Similarly so, with irradiation — as well as creep due to ordinary thermal causes, irradiation can give rise to tiny zones of high stress which induce additional creep in the metal. For these reasons large grain sized metal would, after prolonged irradiation, exhibit severe roughening or wrinkling on the surface. Heat treatment is employed, therefore, to give the uranium a fine random grain size.

canning

The operation of enclosing the uranium bar is one of these apparently simple, straightforward production jobs which in practice proves to be astonishingly complicated in order to achieve the high standard of quality needed.

To start with, the canning material used must be compatible with both uranium and the reactor coolant; it must possess good heat transfer properties, maintain close heat transfer contact with the uranium, and have a low absorption cross-section for neutrons. Under the conditions of irradiation and thermal cycling, it must keep dimensional stability and not change in properties in a detrimental way.

The cost of failure of a fuel element in service is very high and reliability is most important. This leads to an extremely closely defined specification for a fuel element, a rigorous testing routine and a very high inspection standard. Nevertheless, the efficiency for the Windscale and Calder fuel element production lines is of the order of 90% - 95% (the efficiency from cast bar to finished bar is similar).

The can used for the Windscale reactor fuel element (this goes into an air-cooled graphite moderated reactor) is made of aluminium, which is of particularly low absorptive cross-section for neutrons. Although the record of this metal in service in those reactors has been excellent, it is known that uranium and aluminium can react together to form a compound, $UA1_3$ with a much larger volume than the metals forming it. Formation of this compound can cause a can to bulge and fracture. Fracture of a can in a reactor can cause oxidation of the uranium, with consequent dispersion of the uranium and fission products into the cooling gas stream. This means the dispersion of heavy radioactivity into unwanted places and so is to be guarded against. Introducing a non-reactive layer between uranium and can has prevented this kind of interaction, but if conditions arise which rupture the layer, metal to metal contact will result.

In the Calder Hall reactors the fuel elements are arranged vertically and are stacked one on top of the other, each fuel element bearing the weight of those above it. This arrangement was adopted in order to achieve simplicity and to save the time and experimental work which would have to be devoted towards achieving an arrangement in which the fuel elements were separately supported. The arrangement naturally loads each fuel element as a strut and because at the temperatures which are achieved in the reactor the creep stress of uranium is low, there is a possibility that the fuel elements may bow under this load. This may be serious if the bowing becomes excessive because it can make discharge of the fuel elements difficult. For this reason, experiments on creep have been vigorously pursued and it was reasonably predicted that the worst conditions of creep would be towards the centre of the reactor where, although the load on the fuel elements is not at its maximum, the temperature is higher.

This brief review of some of the problems entering into the production of finished fuel elements shows itself up in the cost of these elements, of course. It has been forecast that the long-term price of uranium concentrates is likely to be maintained at about £10,000 per tonne of uranium. The cost of extraction from the concentrates and purification is now relatively small (but used to be quite high). The cost of reduction to metal, casting bars, machining, heat treatment and canning is very considerable, however. Even for aluminium or magnesium alloy cans, the price of complete natural uranium fuel elements for nuclear power stations will probably be of the order of £20,000 per tonne of uranium.

future developments in fuel element production

Sufficient has been said to show that the metallic uranium, cast and machined bar type of fuel element has already been developed to a well-engineered unit, capable of being mass-produced in large quantities,

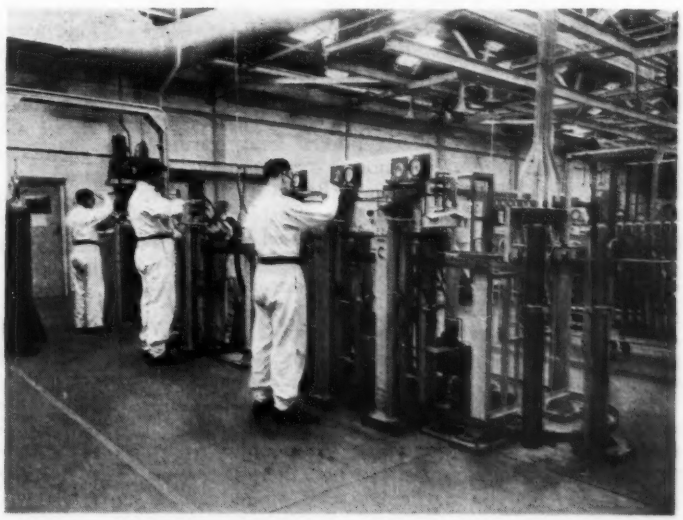


Fig. 3. Uranium canning

Fig. 4. Fuel element pressurising

as is required by the nuclear power programme. But, naturally, our thoughts have been ranging further afield and other types of fuel element are in production and at an advanced stage of development.

The plate type fuel element is one such. This consists basically of a homogeneous alloy of uranium with another metal, say aluminium, rolled into plates which are cropped and trimmed to size. After cladding in a suitable envelope which is completely sealed and welded, it is then possible to incorporate such plates into a variety of assemblies according to the function of the reactor and the cooling medium employed. It will be appreciated that the employment of large relative quantities of metal other than uranium demands the use of enriched uranium to enable a reactor of conveniently small size to be constructed. The heavy water moderated materials testing reactors use plate type fuel elements.

At Dounreay, the first large-sized reactor in this country to employ fast neutron fission is nearing completion. The design of this reactor, which has no moderator, has raised many problems, in particular the removal of very large quantities of heat from the very small volume of the reactor core. To do this requires an extremely unconventional heat transfer system, involving the use of molten metal pumped in circulatory flow. This has required the development of a fuel element canned in a material capable of withstanding high temperatures and the attack of molten metal. The conditions of fast neutron fission naturally create demands for materials of unusual nuclear properties.

The outer can of the fast reactor fuel element consists of a tube of pure niobium, a rare and unusual metal. Contained within this tube is an annular enriched-uranium fuel element with a second unusual metal, vanadium, employed as an inner tube running down the middle of the assembly. Apart from their special nuclear properties, there is a very good reason for this particular selection of metals. Overheating of the uranium during fission caused, say, by an interruption in the flow of coolant would very rapidly cause the metallic uranium to melt. In such circumstances, the vanadium inner tube would fuse long before the niobium outer sheath was attacked and would release the molten uranium which could then flow away harmlessly into a receptacle beneath the reactor, where the nuclear reaction would cease.

It is becoming increasingly clear that for future reactor systems, the attainment of higher temperatures will be essential. For such systems, metallic uranium even when alloyed with other metals is too limited in its potentialities. The development of non-metallic materials of a refractory nature containing uranium or plutonium has received much attention in recent years and already several designs are at a very advanced stage. The problems are formidable, but we can be confident that the eventual attainment of high temperatures will not be limited by fuel element design considerations.

Other problems exist in fuel element design and construction — the solution to them is a major part of the solution to the future development of nuclear reactors. In particular, the utilisation of plutonium produced in the graphite-moderated civil reactors raises many problems, too varied for discussion during this short Paper. I hope that what has been said has been enough to show you the trend of progress in this field.

nuclear power for propulsion

The use of nuclear power for propulsion is dependent upon factors which vary from one application to another. Requirement of mobility immediately sets size limitations in most cases, and weight can also be a very restrictive variable. In general, choice of the reactor system and the subsequent design are governed by several factors and these include :-

1. safety during normal operation ;
2. safety following an accident ;
3. physical size and weight of the power unit (which is influenced by 1 and 2) ;
4. the economics of development and operation.

Safety during normal operation has to be generally assured by adequate shielding of the reactor. The reactor shield has three main functions — slowing down fast neutrons, the absorption of escaping thermal neutrons and the absorption of gamma radiation. A complete concrete shield might be 6 ft. thick, though by the use of other materials (e.g. steel and water), this might be reduced to 3 ft. Not much further reduction can be expected and such a shield will weigh over 100 tons. By limiting the working times for personnel in the vicinity of the reactor to, say, 24 hours per week, shielding might be further reduced to about 4 in. - 6 in. on steel and water. Additional reduction of weight is possible by splitting the shield, i.e. allowing some of the radiation to be stopped by protective clothing worn by the operators. In aircraft particularly, shadow shielding can be used, that is, locating the reactor well away from the crew space and just using shielding between crew and reactor. This not only has complications during maintenance and when the aircraft is on the ground but also when flying, as there may be appreciable back-radiation from the air and from the ground. Information on this reflected radiation is not easy to obtain and in the U.S. a tower facility has been erected. This comprises four 300 ft. high towers with a small reactor suspended in the air between them, so that measurements can be made on mock-up arrangements of aircraft shield design and on air and ground scatter of radiation. Other tests have been carried out with an aircraft (a B.-36) carrying an operating reactor. The reactor did not provide any power for the aircraft, but acted merely as a source of activity.

Safety in operation for ships and submarines is not so difficult to achieve as for aircraft, as the weight limitations are not so severe. In three years' operation of the U.S.S. Nautilus, the first atomic powered submarine, the mean dose for the personnel has been less than 10% of the working tolerance. This is the result of careful design of the shielding.

Following the shut-down of a reactor, there is a considerable amount of heating from radioactive decay products. This build-up can cause considerable heating of the fuel elements — sufficient to cause fire in some cases. From this point of view, it is desirable that fuel elements used should be non-inflammable. As a major accident could well be accompanied by a release of the cooling medium, it is also desirable that this should not become radioactive in use. If this is so, it leads to simplification of the shielding problem as well.

The physical size of the reactor is governed by the particular reactor system used and the shielding necessary. Nautilus uses a Pressurised Water Reactor

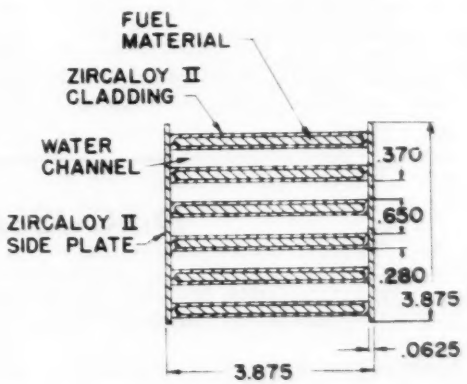
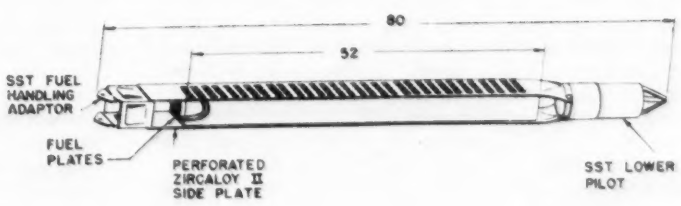


Fig. 5. A plate type fuel element (E.B.W.R.)



(P.W.R.) which is fuelled by plate type uranium elements. The reactor uses highly enriched uranium as its fuel and the uranium charge cost must be about £1m. The effective life of the charge is 2½ years with 200 days per year operation. The capital cost of the equipment would be about £7m compared with £1m for a conventional power plant, and the result is that the fuel costs for a nuclear submarine or similarly for a ship with this type of reactor, are about 10 times that when using conventional oil burning equipment.

Furthermore, a reactor for spasmodic operation will have to be rather extravagant in its use of fissile material. On shutdown a thermal reactor builds up fission product decay residues which are strong absorbers of neutrons. This effect results in a normal reactor being inoperable for a few days following a shutdown, but it can be overcome by using an excess of fissile material to provide excess reactivity. Sufficient control rods have to be installed to balance out this excess reactivity during normal operation.

Enriched uranium reactors in development for propulsive purposes are nearly all being subsidised by governments. Amongst interesting projects under consideration is a Japanese oil tanker which will be a submarine of 20,000 tons dead weight, probably using a sodium graphite reactor developing 20,000 h.p. giving a submerged speed of 22 knots. A firm of naval architects are also designing a 68,000 ton tanker.

The means of transforming developed nuclear power into the propulsive force in the vehicle will vary greatly. It has been suggested that a closed cycle gas turbine may provide a useful solution to the problem. Design studies of the economics of producing nuclear powered small vehicles (e.g. locomotives and aircraft) are not too optimistic. A figure has been published in the United States quoting the production of a large locomotive as being twice as costly as for a diesel engine.

It might be interesting to outline the probable costs of development for a reactor system for an application such as we have described. The zero energy facility which will be the first reactor experiment involved may cost from £100,000 to £250,000, e.g. two were used at Harwell (Zephyr and Zeus for the fast reactor development at Dounreay). Construction of a tower facility might cost £1m and the carrying out of experiments on fuel elements will need the construction of reactor loops at a cost of, say, £100,000 each. After all this work it will be necessary to build a land based prototype reactor which may cost £10m, and this is before we have to relate the project to its final shape.

For aircraft, the preliminary work would take several years and the design construction and prototype stages several more; in fact, it would be unreasonable to expect the construction of a prototype reactor in less than 15 years from the commencement of work on the project.

Nuclear power has, of course, a very real contribution to play in transportation in the United Kingdom providing, as it does, economic generation of base load electricity which can be transmitted to railways at relatively low cost. It has been estimated that the coal consumption of the railways of this country is likely to be cut from the 12,000,000 tons per year of today, to about 5,000,000 tons in the 1970's. Of course, the date of this final realisation will depend to a large extent on the financial policy of the Government but whatever happens, it must be clear that it is in this direction that the immediate application of nuclear power to transport is going to be felt.

DISCUSSION

In the Chair:
Mr. B. G. L. JACKMAN, M.I.Prod.E.,
Midlands Region Chairman.

Mr. L. W. Farrer (*Villiers Engineering Co. Ltd., Wolverhampton*), who opened the discussion, said that basically, they were talking about producing heat and, of course, heat was something which mechanical engineers knew how to handle. It was a wonderful example of engineering and the problems which had beset Dr. Littlechild were fantastic.

So far, they had not been given much hope of cheaper energy in the future, and Mr. Farrer asked whether, by 1965 - 1970, they could hope to find some reduction in the cost of electricity ? Many years ago, there was a joke about 'carrying coals to Newcastle', but in spite of the efforts of the coal industry, the U.K. now had to import coal.

Dr. Littlechild, in reply, said that Sir Christopher Hinton, who took up the post of Chairman of the C.E.A., examined this question very closely in the Paper he gave recently in Sweden. One difficulty was that they were really reviewing costs against inflationary disadvantages. Prices must rise, and coal was costing more to get. There was the fact that coal was becoming more difficult and more expensive to mine. Sir Christopher Hinton estimated that by the mid-1960's the cost of power from atomic power stations should become comparable, but the price at the moment was balanced by the fact that the nuclear power stations were producing military plutonium. After mid-1960, nuclear power costs should fall, but this would depend upon our ability to design large pressure shells. Certainly by the early 1970's power costs should begin to fall. By 1980, Dr. Littlechild could see power no longer becoming an expensive commodity. Production of power could be unlimited.

Mr. L. R. Evans (*The English Electric Co. Ltd., Stafford*) asked if the Atomic Energy Authority was developing a beryllium can ?

Dr. Littlechild, confirming this, said that beryllium had some extremely difficult properties as a can material, the most important being the great hazards associated with it. Beryllium was extremely dangerous to health. The dust was very poisonous and there was beryllium poisoning of the lungs. Until they knew how to overcome these problems, there were going to be a lot of complications.

Mr. Edwards (*Accles & Pollock, Oldbury*) commented that fuel elements were presumably needed in very large quantities for the next stages of power generation and necessitating the provision of considerable facilities by industry; what was the use of them in terms of time ?

Dr. Littlechild thought there was no doubt at all that we should have to run power stations as presently designed and the useful life must be 20 years plus. They were going to cost a fair amount of capital, and we should just not be able to write off the Calder Hall type reactors. It was desirable for steam generation purposes to produce steam at as high a pressure as possible.

Mr. Shipton (*J. Brockhouse & Co. Ltd., Wolverhampton*) asked if it was possible to can uranium, and what machine tools would be used ?

Dr. Littlechild replied that materials were canned in order to contain fission products. Some of these were gases or materials which would react with oxygen and would produce dust and powders, burning like zinc. A burst cartridge, i.e. with a slight weld failure, would be sufficient to shut down a reactor.

Tungsten carbide tipped tools were quite satisfactory to give quite a normal machined finish. An interlayer was needed when using uranium within aluminium cans, otherwise there was a chemical reaction between them.

In reply to a question as to how long Calder Hall type reactors would continue to be built, **Dr. Littlechild** said a very long life was predicted for the Calder Hall type reactor. It was now considered to have an even longer life than when the first White Paper was produced. This White Paper saw three stages, and it was envisaged that the Calder Hall type might only be built up to about the 1966 period, but they were capable of further development. Hydrogen as a coolant gas was being explored. There were obvious disadvantages, but on the other hand there were some great advantages. It was an extremely light gas and, moreover, it had other properties which were very attractive.

In reply to a question as to whether, at this stage, there were any cases where heat and not power was being taken from the pile, **Dr. Littlechild** said this was so at Windscale and Harwell. There was also a reactor being developed in Europe which was producing steam entirely for process purposes.

Mr. Barlow (*Audley Engineering Co., Newport*) asked Dr. Littlechild what he considered to be the future of the gas-cooled type of reactor when or if it was superseded by liquid ? The reply was that a long life was envisaged for this type of reactor.

In reply to **Mr. Kenyon** (*Tube Investments Ltd.*), who asked if there was any future in stainless steel for material in reactors, **Dr. Littlechild** said that the first power station made by the Russians was about one-tenth the size of the Calder Hall station. This used stainless steel canned fuel elements, which was a very expensive system. Such a reactor could not be fuelled on natural uranium. Stainless steel was a very good canning material, but its neutron-absorbing properties made it a difficult material to use. Neutrons were a valuable commodity and the cost of neutrons must be borne in mind.

Mr. L. R. Evans said he understood that the Japanese were interested in the establishment of a power producing reactor of British manufacture, but was it Dr. Littlechild's opinion that we were likely to be able to continue fuelling this reactor, and could we become one of the major exporters of power reactors to other parts of the world ?

Dr. Littlechild replied that, of course, we hoped to be. This could be a very good line of business, and very valuable to the electrical industry.

The Japanese had a similar fuel problem to that of the British. They had limited natural fuel resources, as compared with those of the Americans or Russians. If the Japanese could be persuaded to develop a technology based on Calder Hall reactors, this was very good business for Britain, as it meant that their fuel element development was following a similar pattern to ours.

Mr. Hingston (*John Thompson Ltd.*) asked to what extent would this counterbalance British coal imports, in regard to economics ? Would what was being built today be out-of-date by the time it was built ?

Dr. Littlechild said the answer was "When does it become out-of-date ? Until somebody can show you that his power station is a better economic problem, you will run the one you have got and presumably we can design gas-cooled nuclear power stations which will last 20 years and perhaps longer. This means that you have got to have a good economic proposition before going over to another system. A new system may use the uranium more efficiently — you take out the uranium, reprocess it economically and put it back again. You can do this until you have burned up all the Uranium^{235} contained in it. I think that the input of new uranium to an existing gas-cooled reactor system would be quite small, therefore, the fuel costs would be small".

(*concluded on page* 384)

Output Pattern in Repetitive Tasks

with special reference to
Compensating Relaxation Allowances

by **N. A. DUDLEY,**
Ph.D.(Birmingham), B.Sc.(London), M.I.Prod.E.

PART IV

Conclusions, and general statement of principles of application

performance variations during work periods

A comparative analysis of the recorded data reveals that when trained and experienced workers are engaged on repetitive manual or manually controlled operations (which have been standardised as to the method of working and work content) during the periods of time which are regarded as normal in current practice, their performances display certain characteristics which are common to the wide range of tasks studied.

These characteristics are as follows :-

1. Operation and constituent element times are substantially constant, within close limits, throughout the working day, with no statistically significant trend discernible.
2. The range of element times throughout the working day is no greater than that which could be expected to arise from random variations, and there is no statistically significant trend.
3. Variations which occur in the pattern of motion element times are attributable to voluntary changes in the operator's working pace.
4. Personal delays, under the worker's control, where these occur, tend to be grouped towards the beginning and end of each work period.
5. A slightly greater percentage of time (but not necessarily more time) is lost by reason of personal delays during the afternoon than during the morning work period.
6. Ancillary work and operational delays, where these occur, tend to be grouped towards the beginning and end of each work period.
7. Non-standard or " foreign " operation elements result from the interruption of the repetitive work pattern by personal or operational delays.

Differences between workers

(a) ***on the same operations***

While the characteristics noted above are typical of all the operations studied, it was found that differences in average element times, and hence in the average working pace, achieved by different workers on the same tasks, could not be explained solely in terms of consistently higher or lower levels of performance.

Analysis of the histograms of element times, in such cases, indicates that these differences in performance are associated with differences in operator's skill and experience.

(b) ***on different operations***

In spite of differences in the nature of the work, in the degree of physical effort and of attention required, and in the sex of the operators, time lost through personal delays varied only slightly. Such time (including the " tea break ") did not exceed 10% of the work shift. Incidentally, the time lost was least in the case of female workers engaged on what appeared to be most arduous work (operation 18).

Operational delays and ancillary work

Although all the operations studied were highly repetitive and performed continuously throughout the day, there were considerable differences between the operations in the amount of time lost by reason

of operational delays — preparation and waiting time — and ancillary work. In the case of light work, probably due to more effective planning of production, very little time was lost through operational delays.

Where such delays occurred, they tended to be grouped — as in the case of personal delays — towards the beginning and end of work periods, and were mainly responsible for the general "late start" and "early finish".

As noted above, these operational delays had the effect — similar to that of the personal delays — of introducing non-standard elements into the operation cycle.

Output curves

The shape of the "typical saddle-back" output curve is to be accounted for largely in terms of lost time due to ancillary work, operational delays and, to a less extent, personal delays. Indeed, the output rate curve approximates very closely to the curve recording the distribution of productive and non-productive time.

Hence, the first of the preliminary hypotheses stated above, to the effect that: "During the work shift, the operator increases his pace to a maximum which he maintains until physical or mental 'fatigue' result in a gradual reduction in pace from work cycle to work cycle, towards the end of the working period" must be rejected in favour of the second which states that: "During the work shift, the operator maintains a consistent working pace, but interruptions, due to personal and operational delays and ancillary work, result in trends in the rate of output".

Clearly, therefore, no valid hypothesis concerning operator's working pace can be based upon the output curve, to which variations in the time taken by workers to perform operation elements make no significant contribution.

C.R. allowances

It is, therefore, in the analysis of lost time, rather than of operation time, that the need for fatigue, relaxation or other allowances is to be sought.

Allowing for the fact that, in exceptional circumstances, special allowances may be required, due to the effect on operator performance of, for example, abnormal working conditions, the range of C.R. allowances given in practice is greatly in excess of time actually lost by reason of personal delays.

It is suggested that the reasons for this practice are:-

1. that an allowance of time is needed to accommodate ancillary work and operational delays (which are often not catered for otherwise, or only inadequately so);
2. the fact that (due to lack of clear definition of the task) the basic conditions necessary before time study should be undertaken are frequently not checked in practice;
3. the failure to appreciate that an allowance for "fatigue effect" is provided, to some extent, in the establishing of a concept of normal pace, in the process of rating;
4. the deliberate inflation of C.R. allowances, in some firms, to compensate workers on low basic rates of pay by increasing their piecework earnings.

Principles to be observed in the determination of time study allowances

1. Before a time study is undertaken, it is necessary to ensure that the operation to be studied has been standardised *via* prior method study, and clearly defined, and that the operator, trained and experienced, is working in the approved manner, under normal working conditions, and producing satisfactory work.
2. When the conditions necessary for the taking of a time study have been established, long production studies — or, where appropriate, activity ratio studies — should be undertaken to determine the causes and duration of non-productive time.
3. While time studies need to be made for every individual operation, production studies need only be made for each class of work or type of process.
4. Insofar as non-productive time arises from inefficient production planning or supervision, action should be taken to eliminate this, both to increase the time available for productive work, and to reduce the number of "foreign elements" arising from such interruptions.
5. Where non-productive time is "unavoidable", special and separate allowances of time for "ancillary work" or "non-standard conditions" should be given to cover these contingencies. (Unless this is done, labour productivity figures are of little value, and can give rise to inaccurate and misleading interpretations.)
6. The frequency of operation element times, derived from production studies, should be plotted in the form of histograms as checks on:
   (a) working pace, which can be assessed both from the shape of the histograms and from equivalent ratings; and
   (b) the trend of times from one work period to the next. In the event of significant trends, examination should be made of the frequency and distribution of lost time. Should this not account for the trends, it is most likely that variations in the method of working have been introduced.
7. Having by elimination or by provision of special allowances accounted for operational delays revealed by production studies, personal delays can then be analysed. Lost time attributable

to personal needs should not normally exceed 5% of the work period, while that required for relaxation will not normally exceed an additional 5%, including any tea break.

Further research on C.R. allowances

While, for the purposes outlined above, long production studies or activity ratio studies have been shown to be essential in all works using time study, it would appear that work simplification, motion study and mechanised materials handling have rendered unprofitable any major research project to establish C.R. allowances for general use in time study practice where normal working conditions occur.

The definition in many industries of what constitutes "normal" or optimum working conditions is, however, by no means clearly established. It is, therefore, suggested that the research techniques used in this thesis might be applied with advantage to a wider range of manual operations, in conjunction with physiological studies, to establish, on a basis of direct observation, the limiting conditions beyond which C.R. allowances, additional to those found to be necessary in the operations studied, may be required.

On the basis of such data, the magnitude of the allowances for relaxation required by workers on repetitive manual operations might then be regarded as an index of the efficiency of the design of those operations, and of the degree of abnormality of the working environment.

The necessity for further work on rest periods and fatigue is most obvious in the case of mining or other operations which often require to be carried out in cramped postures, or under extremely hot and humid atmospheric conditions. In such cases, the effects of the abnormal conditions on the health and working capacity of the worker is of great importance and of equal interest to the physiologist and the engineer.

(Parts I, II and III of this Thesis appeared in the March, April and May issues of the Journal.)

"PRODUCTION PROBLEMS ASSOCIATED WITH INDUSTRIAL ATOMIC ENERGY"—

concluded from page 381

Mr. Goodacre (*John Thompson Ltd.*) enquired what fraction of the initial cost of the fuel was the reprocessing and what approximate period was envisaged for the running of initial charges ?

In reply, **Dr. Littlechild** said that questions on economics were difficult. Uranium fuel elements cost £20,000 per ton. It was hoped to achieve an irradiation life of 3,000 megawatts a ton, but that depended on the power level. If it was burnt up slowly, it lasted longer.

The Chairman, **Mr. B. G. L. Jackman,** M.I.Prod.E. (*Lockheed Hydraulic Brake Co. Ltd.*), asked Dr. Littlechild if he would enlarge on some of the human problems of radiation. Mr. Jackman understood that the limit in some cases was 12 minutes a day.

Dr. Littlechild replied that a distorted picture of radiation hazards was often presented. They were all exposed to radiation right from the day they were born. It was a natural part of their environment and all they were concerned with was what level of radiation was acceptable. The food they ate might be very slightly radioactive, and they were certainly all exposed to it — even the walls were slightly radioactive. The Medical Research Council had advocated caution in the use of X-rays. They should not be cancelled out, but should be used with caution. It was obvious that some parts of the body would withstand more radiation than others. A very high dosage of gamma rays could kill instantly, but a worker could receive a permitted average dose daily and remain unaffected. The health standards of the A.E.A. were very high and were well maintained, both in regard to radiation safety and general industrial health.

Mr. Scriven (*Villiers Engineering Co. Ltd.*) asked, if hydrogen were used, would this offset saving regarding the actual cost of the reactors ?

Dr. Littlechild's answer was that the controlled thermonuclear reaction they knew only a little about, but he could not see power costs coming down rapidly on this account. To maintain a thermonuclear reaction required the fantastic temperature of 100,000,000°. It was quite a different task from the development of a thermonuclear weapon.

Mr. Edwards (*T.I. Group Services*), speaking of the training of technical staff, commented that advances had been made in the last 10 years since the A.E.A. was formed, but in the meantime, technical colleges and universities had been turning out engineers and technologists with little knowledge of nuclear engineering. Did this raise any special problems in obtaining the required quality and quantity of technical staff and did they need any special training ?

Dr. Littlechild thought that staff should be specially trained for atomic energy work, and the technical quality should be high. There was a need for not only a good engineer to run a power station, but also for an expert physicist who understood its implications in detail, and would have a clear picture in his mind. Some kind of dual control was going to be needed in the future.

REPORT OF THE

MEETING OF COUNCIL

Thursday, 24th April, 1958

THE last Council Meeting of the 1957 - 1958 Session was held at 10 Chesterfield Street, London, W.1, on Thursday, 24th April, 1958. The meeting, at which the Chairman of Council presided, was attended by 24 members. Also present, by invitation of the Council, were Mr. J. R. Widdowson, Chairman of the Sheffield Section; Mr. H. F. Harker, Honorary Secretary of the Ipswich Section; and Mr. J. Rook, Chairman of the Sheffield Graduate Section.

Election of Principal Officers, 1958 - 1959

In accordance with notice given at the January meeting of the Council, it was proposed by the Chairman, and unanimously carried, that the following Principal Officers be elected for the year 1958 - 1959 :-

President : The Rt. Hon. The Earl of Halsbury, F.R.I.C., F.Inst.P.
Vice-Presidents : Mr. J. E. Hill; Mr. G. R. Pryor.
Chairman of Council : Mr. H. W. Bowen, O.B.E.
Vice-Chairman of Council : Mr. R. H. S. Turner, M.A.(Cantab.).

In submitting these proposals, the Chairman commented on the Institution's good fortune in having such a very active President. On behalf of the Council he thanked Lord Halsbury for his services over the past year, and expressed their gratitude that he was prepared to accept office for a further year.

With regard to Mr. Hill and Mr. Pryor, the Chairman felt there was really nothing for him to say, because their record of service to the Institution was worthy of whatever honour could be bestowed upon them as Vice-Presidents.

Mr. Bowen's interest in and activities on behalf of the Institution were widely known, and there was no doubt that in him, the Council would have a most capable Chairman. The Institution was especially grateful to Mr. Bowen for the way in which he had carried out the liaison work with overseas Sections during his term of office as Vice-Chairman.

Finally, the Chairman expressed his pleasure that Mr. Turner had acepted the office of Vice-Chairman of Council.

Each of the newly-elected Officers, in a brief address, thanked the Council for the confidence shown in them.

Commenting that the present occasion was the last at which he would preside, the Chairman expressed his warm appreciation of the Council's support during his term of office.

Mr. F. W. Cranmer

The Chairman drew the Council's attention to the fact that one of their best-known members, Mr. Frank Cranmer, had now retired from business, and was attending his last Council Meeting in an official capacity.

Mr. Cranmer intended to continue his Section activities, for which those in the North-West were very grateful. The Chairman knew from personal experience what a wonderful job Mr. Cranmer had done for the Institution during the many years he had held office of one kind and another. Not only had he attended Council, and served as a Section Chairman and Section Honorary Secretary, but he had also done valuable work as a member of the Education and Membership Committees for a great number of years.

He extended to Mr. Cranmer the good wishes of the Council for his retirement, and invited him to attend meetings of the Council whenever he happened to be in London and wished to do so.

Finance

The Finance and General Purposes Committee were pleased to report that in spite of increased costs during the year, the surplus of income over expenditure was likely to exceed the amount budgeted. This was partly due to the loyal response of members in the prompt payment of their subscriptions, and partly because of economies effected in the Headquarters administration.

Production Exhibition and Conference, 1958

It was reported that all arrangements for this event had been completed, and details circulated to members. In February, a Press Conference, held at Head Office, and addressed by the President, Lord Halsbury, had attracted 120 representatives of the National and Technical Press, who were given the opportunity of meeting the Conference speakers and members of the Organising Committee.

Co-operation with Polish Society of Mechanical Engineers

It was reported that a party of 10 members of the Institution, together with the Secretary, would be flying to Warsaw on 27th April, 1958, at the invitation of the Polish Society of Mechanical Engineers, for a 10-day tour of Polish industry. A reciprocal visit of Polish engineers to the U.K. would take place towards the end of May.

Revised Associate Membership Examination

The Education Committee reported that booklets on "Subjects and Syllabuses for the Associate Membership Examination" and "Notes for Guidance" have been issued to technical colleges, training officers, etc., and specimen examination papers were now available.

The Exemptions Sub-Committee had met twice to consider exemptions that may be given on the new examination scheme.

Summer School

It was announced that the theme of the 1958 Summer School, to be held at Ashorne Hill, Warwickshire, from 27th-31st August, would be "The Advancing Frontiers of Production Engineering", and that the nine lectures in the programme would be based largely on the Management 'tool' subjects of Part II, Group C, of the 1960 Associate Membership Examination (see Supplement to this Journal).

Elections and Transfers

The Council approved a number of applications for membership and transfer, details of which appear on pages 387 - 388 of this Journal.

Membership Theses

It was reported by the Membership Committee that Notes for Guidance were now available to candidates submitting theses.

The Journal

The Editorial Committee advised the Council that an adequate and varied supply of material for publication continued to become available, and there had been considerable demand outside the membership for the January and February issues.

The sale of advertising space showed an encouraging upward trend for the first three months of 1958, but the constant and increasing support of members of the Institution was required if this trend was to be maintained.

Institution Papers

It was reported by the Papers Committee that the meeting at Bristol University on 6th February last, for the presentation of the 1958 Viscount Nuffield Paper by Lord Hives, drew a capacity audience, and was a most interesting and enjoyable occasion. Mr. G. R. Pryor, Vice-President, was in the Chair.

Lord Hives' Paper, "Technical Education for Production Engineers — Some Reminiscences and Experiences", appeared in the April issue of the Journal.

There was also a full attendance at the University of Leeds, on 24th March, to hear Dr. V. E. Yarsley present the 1957 George Bray Memorial Lecture, entitled "The Fabrication of Plastics". This was a most comprehensive Paper, which would appear in the July issue of the Journal.

The Committee were also pleased to report that Sir Cecil Weir, Past President, had accepted their invitation to present the 1958 Sir Alfred Herbert Paper, in London, on 11th December next. His subject would be: "European Free Trade — Its Origins and Implications".

Research

The following reports were made on behalf of the Research Committee:

MATERIALS HANDLING GROUP. Three meetings of the Group Committee had been held during the quarter, and arrangements had now been made for the 1958 Group Convention to be held in Brighton on 13th - 15th October next. The Convention would be devoted almost entirely to syndicate work covering the investigation and solution of specific handling problems at certain factories in the Brighton area. The Group Committee continued to participate in the work of the National Joint Committee on Materials Handling.

MATERIAL UTILISATION. The Sub-Committee had met twice during the quarter, and their Report was now being prepared in final draft form.

SOURCES OF INFORMATION. There was nothing further to report in regard to the preparation of the Directory.

CONTROL OF QUALITY. The Sub-Committee had held five meetings during the quarter, and had completed work on the final draft of the Report.

JOINT RESEARCH COMMITTEE WITH I.C.W.A. It was expected that a meeting of the Committee would shortly be called, when the sub-committees had prepared reports on their progress.

Standardisation

The Chairman of the Standards Committee, Mr. H. Stafford, reported that an invitation had been received from the British Productivity Council to join the Committee on Variety Production.

It had been noted with satisfaction that, following representations from the Standards Committee, B.S.I. had started work on the standardisation of unit

heads. There were now 148 Institution members serving as representatives on 117 B.S.I. Technical Committees.

With regard to the Fourth Annual Conference of Standards Engineers, organised jointly with B.S.I., plans had now been completed, and the Conference would take place in the Connaught Rooms, London, on 21st May, under the Chairmanship of Mr. Stafford.

Region and Section Reports

The Council received a number of reports from Regions and Sections, extracts from which appear on pages 389 - 394 of this Journal.

Sections outside the United Kingdom

The Vice-Chairman of Council (Mr. H. Bowen, O.B.E.) gave a brief report of his liaison with overseas Sections of the Institution during the quarter under review.

Members in Arrear with Subscription

The Council adopted a recommendation of the Finance and General Purposes Committee that a number of members be removed from the Register, because of non-payment of membership subscriptions.

Schofield Travel Scholarship

It was recommended by the Finance and General Purposes Committee, and unanimously carried, that in future a Schofield Travel Scholarship should be awarded every third year, and that the value of the Award be increased to £750.

1957 Lord Austin Prize

It was reported by the Education Committee that the 1957 Lord Austin Prize had been awarded to Mr. J. Percival, Graduate, who proposed to use the Award to visit the Brussels Fair.

Obituary

The Council recorded with deep regret the sudden death of Mr. J. A. Bailey, Member, who had served on the Education Committee for some time, and also the deaths of the following :-

Member : J. Tindal.
Associate Members : G. Kirk; A. W. Turner; F. K. Webster.
Student : J. Mills.

Date and Place of Next Meeting

It was agreed that the next meeting of the Council would take place on Thursday, 24th July, 1958, at 10 Chesterfield Street, London, W.1, at 11 a.m.

ELECTIONS AND TRANSFERS

24th April, 1958

ADELAIDE SECTION
As Associate Member
Z. G. Golley.

BIRMINGHAM SECTION
As Associate Member
K. A. Norton.
As Graduates
D. A. Burbridge; J. P. B. Ablewhite; J. W. E. Walker; B. M. Palmer; D. Steele; D. H. Davies; P. W. Thorne; J. M. Hoyte; B. H. Tummey.
Transfers
From Graduates to Associate Members
A. M. Cooper; C. A. Edwards.
From Students to Graduates
D. A. Taylor; K. Maddison.

BOMBAY SECTION
As Student
K. C. Sharma.
Transfers
From Associate Members to Members
I. Mann; P. S. Kharas.

CALCUTTA SECTION
As Student
R. K. Agarwal.

CANADA SECTION
As Associate
C. M. Rodkiewicz.
Transfer
From Student to Graduate
F. R. Taylor.

CARDIFF SECTION
As Graduate
F. Farrar.
As Student
Z. I. Rudnicki.
Transfers
From Associate Members to Members
H. G. H. Dixon; R. L. Aston.

COVENTRY SECTION
As Member
G. E. Phipps.
Transfer
From Associate Member to Member
R. N. Cook.

DERBY SECTION
As Graduate
L. A. Sims
Transfers
From Associate Member to Member
A. G. Harling.
From Graduates to Associate Members
J. Hartley; G. A. Parnham; R. J. Keetley.
From Students to Graduates
F. Davenport; A. J. Parker.

DUNDEE SECTION
As Associate Member
R. Simpson.
As Graduates
R. C. Hicks; W. A. McLean.
Transfers
From Associate Members to Members
G. S. Mutch; R. W. Mackay.

EDINBURGH SECTION
Transfer
From Graduate to Associate Member
A. J. C. Johnston.

GLASGOW SECTION
As Associate Members
H. S. Billimore; J. Mackenzie; R. McAdam; W. Johnstone; P. Connelly; J. A. Larkin; A. B. Robertson; J. P. Turnbull.
As Graduate
D. L. McIntosh.
As Student
A. A. W. Mitchell.
Transfers
From Graduates to Associate Members
D. I. McKinnon; H. Bottomley; T. E. Cole.

GLOUCESTER SECTION
As Associate Members
S. Hinchliff; R. Winrow.
Transfers
From Graduate to Associate Member
P. R. Smith.
From Student to Graduate
A. J. Davies.

HALIFAX SECTION
From Associate Member to Member
K. McMahon.
From Graduates to Associate Members
R. Hepper; J. A. Taylor.
From Student to Graduate
N. Varley.

IPSWICH AND COLCHESTER SECTION
As Associate Member
S. H. Potter
Transfer
From Graduate to Associate Member
P. J. Spooner.

LEEDS SECTION
As Associate Members
R. C. Pearson; W. N. Stone; H. T. Hill.
As Students
R. L. Dyson; G. Kirby.
Transfers
From Associate Member to Member
R. Shilton.
From Graduates to Associate Members
D. H. Laycock; J. E. Pitchforth.
From Student to Graduate
L. Swallow.

LEICESTER SECTION
As Member
H. J. Newton.
As Associate Member
P. M. Kendall.
Transfers
From Graduate to Associate Member
R. P. Bull.
From Students to Graduates
H. E. Fisher; M. N. Bown; J. B. Watson.

LINCOLN SECTION

As Associate Members
D. R. Trigg; M. F. Gough.
As Graduate
G. I. P. Clark.

LIVERPOOL SECTION

As Graduates
W. G. Evans; A. J. Steel; K. Black.
As Students
P. L. Wyke; R. H. Mellor.
Transfers
From Associate Member to Member
J. Irwin.
From Graduates to Associate Members
A. R. Stoddart; G. H. Rowlands; H. H. Chesters.
From Student to Graduate
C. Ford.

LONDON SECTION

As Associate Members
P. Andrews; D. Capp; G. Hayward; J. E. Pegg; B. J. Vass; J. J. Pateman.
As Graduates
G. Casson; A. A. Goldring; J. Ingleby; D. H. S. Bunn; R. H. Wadge; B. Simms; V. S. Panandikar; J. D. Colocott; T. D. Tufnell; J. K. Cooling.
As Students
A. J. F. McAlinden; A. M. Crisford; R. D. Bald; A. E. Hayllar.
Transfers
From Associate Members to Members
E. W. Butler; I. H. Nickols.
From Graduates to Associate Members
P. B. R. Fuller; P. Kerrin; A. H. Kynaston; R. S. Eames; G. G. H. Martin; R. M. Webb; G. Dubben; N. W. Davies; G. Cheater; R. J. Temple; I. R. Reid; D. J. Tayson; B. J. Venear; D. A. Morrison.
From Students to Graduates
D. B. Richardson; W. Stevenson; T. J. Smith; A. M. Wring; D. C. Roberts.

LUTON SECTION

As Associate Members
P. J. Barry; L. W. Castle.
As Graduates
J. B. Mowe; P. T. Gray; H. L. Mediratta; A. Menzies Anderson; A. A. Herridge; J. M. Proctor; D. S. Dobell.
As Students
J. W. Miller; D. R. Summerson; N. A. Dilley; G. D. Currie; V. O'Connor.
Transfers
From Graduates to Associate Members
F. Woodgate; K. T. Jackson.
From Student to Graduate
R. G. Hall.

MANCHESTER SECTION

As Associate Member
F. Taylor.
As Associate
S. Soobiah.
As Graduate
R. Fielding.
As Student
J. J. Yates.
Transfers
From Graduates to Associate Members
G. Pickavance; P. H. D. McGain; S. Brown; L. P. Kennett; K. Pollitt; H. F. Mather; M. O. Short.
From Student to Graduate
S. J. Rushton.

MELBOURNE SECTION

As Associate Members
M. L. Summers; R. D. Driver.
New Affiliated Firm
Personnel Administration (Victoria) Pty. Ltd.

NEWCASTLE UPON TYNE SECTION

As Associate Members
R. Taylor; G. Cockburn.
As Graduate
W. V. McGrory.
Transfers
From Graduates to Associate Members
A. D. Bailey; R. F. Loebl; L. Bainbridge; W. M. Thompson.

NORWICH SECTION

As Student
M. H. Briston.

NOTTINGHAM SECTION

As Associate Member
E. G. Scrannage.
As Graduates
P. A. Crecraft; R. Truman.
Transfers
From Graduate to Associate Member
G. F. Brigginshaw.
From Student to Graduate
D. G. King.

PETERBOROUGH SECTION

As Graduate
D. A. Channell.

PRESTON SECTION

As Associate Member
F. D. Smith.
As Graduate
R. B. T. Williams.
As Student
B. D. Britton.
Transfers
From Graduates to Associate Members
D. Staig; H. Calderbank; J. Schofield; J. A. Meara.
From Students to Graduates
R. Higginbottom; B. Grimshaw.

READING SECTION

Transfers
From Graduates to Associate Members
J. Sewell; R. A. Hunter.

ROCHESTER SECTION

As Associate Member
S. Beadle.
As Students
E. W. Munn; D. Blake; F. E. White; D. Neilson.
Transfers
From Associate Members to Members
G. C. Fairbanks; D. Harwood-Jones.
From Graduates to Associate Members
B. E. Thornby; P. F. Thorpe.
From Student to Graduate
J. M. Webb.

SHEFFIELD SECTION

As Associate Member
G. B. M. Rhind.
As Graduates
R. Berger; D. A. Stokes.
As Students
R. Hibberd; K. Woodcock.

SOUTH AFRICA SECTION

As Associates
J. G. B. Thomson; R. G. Matlock.
Transfer
From Graduate to Associate Member
M. I. Berkman.

SOUTH ESSEX SECTION

As Graduates
L. D. Cook; J. Evans; R. F. Jones; R. Charlton.
Transfers
From Associate Member to Member
E. S. Hammett.
From Graduates to Associate Members
D. R. Coburn; L. E. Rodwell.
From Student to Graduate
P. H. Webster.

SOUTHAMPTON SECTION

As Member
S. P. Woodley.
As Graduate
H. W. S. Ree.
As Students
A. D. Randall; P. A. F. Martin; R. Peake; M. D. Arkell-Hardwick.
Transfers
From Associate Member to Member
P. R. Pelly.
From Graduates to Associate Members
R. C. C. Wadey; K. J. Thompson.

STOKE-ON-TRENT SECTION

As Graduates
A. Naim; G. L. Whitby; J. J. Buffey; J. Corbishley.
As Student
D. J. Tildsley.
Transfer
From Graduate to Associate Member
R. F. Briscoe.

SWANSEA SECTION

Transfer
From Associate Member to Member
E. Hoyland.

SYDNEY SECTION

As Member
P. A. Dean.
As Associate Member
H. Beran.

TEES-SIDE SECTION

As Students
G. W. Stephenson; P. D. Roberts.
Transfers
From Students to Graduates
C. Robinson; C. Herrington.

WESTERN SECTION

As Associate Member
R. E. V. Nash.
As Graduate
D. H. Brettoner.
Transfers
From Associate Member to Member
J. G. Norris.
From Graduates to Associate Members
A. Smith; B. T. Aston.
From Student to Graduate
R. W. Wall.

WOLVERHAMPTON SECTION

As Member
G. B. Sheldon.
As Graduates
A. F. Poole; R. O. Brown; C. W. Beech; F. J. Silvester; B. Gibbens; J. A. Bolus; W. H. Kimberley.
As Student
A. J. Smith.
Transfers
From Associate Member to Member
R. L. Nicklin.
From Graduates to Associate Members
J. D. Gutteridge; G. H. Newton; G. B. Williams; H. E. Sleigh.
Transfers
From Students to Graduates
S. S. Brookes; B. Farazmund; D. S. G. Parry; K. C. Gamston.

NO SECTION

As Associate Member
H. M. Falconer.
Transfers
From Graduate to Associate Member
M. J. Silver.
From Students to Graduates
L. E. Salinas-Estenssoro; S. S. Akhtar.

EXTRACTS FROM

REGION AND SECTION REPORTS

January - March, 1958

EAST AND WEST RIDINGS REGION

Halifax and Huddersfield

The main business in the last quarter has been that the two final lectures of the programme have been held. The new Committee and Chairman for the 1958 - 1959 Session were elected at the Annual General Meeting held in February.

The weather on the night of the Annual General Meeting played havoc with the attendance but, nevertheless, those who attended enjoyed a very good evening.

Halifax and Huddersfield Graduate

At the Annual General Meeting held in February, the local prospects for the Institution were discussed. As most young men first meet the Institution through the lecturing staff of technical colleges, it is suggested that a potential recruiting force for the Institution exists in those lecturers who are members of the Institution. Halifax and Huddersfield are fortunate in having the active help and co-operation of the Heads of the Engineering Departments in the respective technical colleges; perhaps other Sections have not pursued this approach.

Employers can also help, especially with Graduates and Students, by employing, all other things being equal, members of the Institution. The fact that a young man has joined the Institution implies that, in seeking professional status, he is willing to study and learn, thereby making himself a potentially better employee.

Leeds

A Materials Handling Group has been formed under the Chairmanship of Mr. J. M. Wilson, and it is hoped that next Session a lecture will be given by members of this Group to the Leeds Section.

The Annual General Meeting was held in March and the following officials were appointed for next Session :-

Chairman: Mr. R. Shilton.

Vice-Chairman: Mr. C. L. David.

Committee: Messrs. J. M. Wilson; R. W. Gunton; W. P. Knox; and J. Leighton.

Secretary: Mr. J. L. Townend.

Assistant Secretary: Mr. J. Keightley.

Following the Annual General Meeting, Mr. W. Nichols, a member of the Section, gave an extremely interesting talk on "The Design and Manufacture of Glass-making Machinery", implemented by photographs and a film.

Leeds Graduate

The Leeds Graduate Section have now completed their programme for the 1957 - 1958 Session. On the whole, this has been a successful year, taking into account the fact that the Section had been non-operative for a number of years and this was the first year in operation since being re-formed.

In an effort to make early contact with new members of the Institution, i.e. Graduates and Students, arrangements have now been made for certificates of membership to be presented to recipients at lecture meetings held by the Senior Section.

Sheffield Graduate

Programme of "Practical" Lectures

The Section's third programme of "practical" lectures has now been completed and, as before, all five lectures were attended to capacity. The lectures were limited to an attendance of 30 and an average of 44 applications were received. Approximately one half of those in attendance were visitors and amongst them were 13 firms not previously represented. This indicates the growing interest in the lectures and the success of the Section's efforts to introduce the Institution's activities to a wider field of local industry. In all, 43 different firms have been represented this year.

The Session was rounded off in fine style with a lecture on "Photography in Engineering" by Dr. L. Mullins, of Kodak Ltd. This was highly entertaining and attracted a capacity audience.

National Graduate Conference, 1959

This Conference is to be held in Sheffield and the date provisionally chosen is 11th April, 1959.

EASTERN REGION

Ipswich and Colchester

An extremely interesting evening was spent in Ipswich during January when a Paper, "Defining a New Era", was presented by Mr. E. R. Davies, of The English Electric Co. Ltd., covering Information, Control, Cybernetics and Electronics.

At the February meeting, a Paper entitled "Designing for Production" was given by Mr. A. P. Peat, M.I.Prod.E., of Baker Perkins Ltd. This lecture was illustrated by slides.

With the March lecture meeting over, a very interesting programme will be successfully concluded. It has comprised the usual six evenings, when first-class Papers have been read, and reasonably well attended.

At recent Committee meetings, much time has been spent preparing the 1958 - 1959 lecture programme. From experience gained by some of the Sections, this programme will include five lectures, the December meeting being tentatively dropped.

Works visits has been an item on the Committee's agenda and it is anticipated that one afternoon and one evening visit will be arranged for the Summer. Discussions are taking place regarding this year's social activities.

MIDLANDS REGION

Regional Report

It was with deep regret that shortly after the last meeting, the news of the sudden death of the Wolverhampton Section Chairman, Mr. G. A. Firkins, was received. Thoughts of all members go to his widow and family as they share the sadness of this bereavement. The services to the Institution rendered by the late Mr. Firkins will long be remembered by those fortunate enough to have known this man of many interests.

In March, in the Sibree Hall, Coventry, the second Regional meeting was held on the subject of "Ceramic Tools". Mr. H. Eckersley and Mr. R. N. Cook presented their joint Paper, "Current Experimental Work with Sintered Oxide as a Cutting Tool". The demand for tickets greatly exceeded the hall's capacity and indicated the tremendous interest amongst production engineers in this new cutting material. Thanks were accorded to all those who made this meeting a success by giving their support, and to Wickman Ltd.

The Midlands Region one-day Conference will be held on Wednesday, 7th May, and will be entitled "Machining Tomorrow's Production"; it will comprise a series of Papers on new techniques in machining, including chipless machining, electro-erosion and computer control. The President of the Institution, Lord Halsbury, will address the Conference. The delegates will then be able to study at first-hand modern manufacturing facilities, for the venue of this Conference is in the Auditorium of Cincinnati Milling Machines Ltd., Birmingham.

On social matters, the Regional Dinner was held on 18th April at the Queens Hotel, Birmingham. The principal speakers were Sir Cecil Weir, Past President; Sir John Eldridge; The Lord Mayor of Birmingham, Alderman J. J. Grogan; and Mr. S. M. Parker.

Mr. H. Tomlinson, Past Chairman of the Wolverhampton Section, has accepted the nomination to serve as Chairman of the Region upon retirement of Mr. B. G. L. Jackman from this office at the close of the 1957 - 1958 Session.

Birmingham

The two lectures given in Birmingham this year have been on widely differing subjects and both were well received. In January, Mr. J. P. Udal gave an illustrated lecture on "Inter-process Mechanisms for Press Work". He dealt with the various methods of linking presses together and providing ejection from them, and showed films to illustrate the points of his talk. He emphasised that expensive equipment was not always necessary and that simple methods could do much in the way of increasing machine utilisation.

The second lecture was given jointly by Sir Ewart Smith and Sir Tom Williamson, who were well able to give the management and Trade Union viewpoints of modern production developments. The viewpoints were well and pungently put and the audience responded with some good questions, which were answered in full detail by each speaker.

The Annual Dinner-Dance was held at the Botanical Gardens in February, and was honoured by the presence of Mr. H. G. Gregory, Chairman of Council, as chief guest and speaker; Mr. and Mrs. B. G. L. Jackman, Mr. and Mrs. Castledine, Mr. and Mrs. Owbridge, and Mr. and Mrs. W. F. S. Woodford, as well as the guests of members.

The major "future activities" of the Section take the form of a visit to The English Electric Co. Ltd., Stafford, in June, which will be the Summer outing and will include a visit to Ingestre Hall in the afternoon. Lunch will be provided by the Company at Stafford, and tea will be arranged at Ingestre.

The other social activity is the Charter Flight to the Brussels Fair on 16th May, which is being actively pressed forward in the Section at the moment — hotel accommodation is booked and all arrangements for the flight are fixed.

Birmingham Graduate

The 1957 - 1958 Session has, so far, been very successful in its attendances at lectures, visits and outside activities. The Christmas Dance at the County Cricket Ground, Edgbaston, was attended by over 100 members, friends and their ladies, making a very pleasant social occasion.

Following the March meeting at the Foley College, Stourbridge, to encourage membership in outlying areas, a further meeting was held at Oldbury College of Further Education in March, 1958. There was an introductory talk by Mr. R. N. Marland, Birmingham Section Chairman, followed by a film show.

Works visits are becoming popular and good attendances have been achieved at visits to Henry Wiggin Ltd.; Josiah Wedgwood Ltd.; H. W. Ward; Metropolitan Carriage & Wagon Co. Ltd.; and Hams Hall "B" Power Station. Lecture attendances also appear to have improved with subjects covering component production from metal powder, by G. R. Bell, B.Sc., and metal spraying by W. E. Stanton.

Work has also been carried out by representatives of the Senior and Graduate Committees to produce a more integrated programme for the next Session. Working on the assumption that no person could possibly attend the whole range of meetings available to him by his membership of various organisations, an attempt has been made to combine certain of the Graduate and Senior meetings to reduce the total number of lectures presented, but to improve the quality and pattern behind their selection so that nothing of their value is lost. This should be implemented in the 1958 - 1959 Session, which is the anniversary year of the formation of the first Graduate Section in Birmingham in 1933.

Coventry Graduate

The practical illustration of the Section's lecture programme has continued successfully. A very well attended lecture by Mr. A. E. Adams, M.I.E.D., on "Modern Centreless Grinding" was held in December. This was followed by a visit to the works of Arthur Scrivener Ltd., Birmingham, in January. Here members were able to see the principles expounded in the lecture put into practice. Another visit, held in January, was to the London Laundry Ltd., where members saw some interesting case studies in materials handling.

The February meeting was held at the works of Smiths Stampings Ltd., where a film on American drop forging practice was shown. After the film members visited the works and were able to make comparisons in the methods used.

Shrewsbury

Attendance at Section lectures has been maintained and the Committee were pleased to see the Midland Region Secretary, Mr. A. C. Turner, at the February meeting.

In view of the importance of technical education, the Section Committee has been concerned at the difficulties experienced by Graduates on the staffs of smaller technical colleges in obtaining transfer to Associate Membership.

It has been agreed that the Section continues to hold its Annual Dinner, the next one being on 14th November, 1958.

Wolverhampton

The affairs of this Section are overshadowed by the sudden and untimely death of the Chairman, Mr. G. A. Firkins, during his second year of office. Those members who attended the Dudley lecture meeting on 8th January could have had little idea that very soon he would be with us no more. He died on Saturday, 18th January, after being rushed to hospital.

This unprecedented loss by the Section has, of course, necessitated commensurate action by the Committee, and Mr. P. J. Shipton has found himself prematurely installed as Chairman without the moral guidance and assistance one can normally expect from one's predecessor. Under the sad circumstances, he carries with him the good wishes of all.

It is gratifying to record that a good strength is being maintained of both long serving experienced members and relatively new young members, all providing keen and active support. In particular, two members, Mr. L. W. Farrer and Mr. H. Tomlinson, now equally share over 20 years' continuous and regular service between them. At the other end, there are now four members nearing the end of their first year, and at the Annual General Meeting held on Wednesday, 5th March, we were pleased to note the election of Mr. D. G. Wiley, a former member of the Graduate Committee.

Facts of this kind provide a source of hope and encouragement for the future.

Wolverhampton Graduate

The death of Mr. G. A. Firkins, the Chairman of the Senior Section, will be mourned by all the Graduate Section, particularly those on the Graduate Committee who came in personal contact with him. He was a very pleasant man,

who never made a young Graduate feel small and unimportant when talking to him, and was always willing to give a helping hand to the Graduate Section.

Efforts are being made to obtain nominations to fill the many Committee vacancies, but without success. An appeal sent out by the Chairman with the election notices has brought no response at all. One of the difficulties in securing nominations is the necessity of obtaining a proposer and seconder. This means that unless the member knows two other Section members quite well, which is often not the case, he must approach people whom he knows are members, but does not know very well, to ask them to propose and second him, which he finds embarrassing.

NORTHERN REGION

Newcastle upon Tyne

The January meeting was well attended, when Mr. E. A. Sweetman presented an interesting Paper on "Spark Machining", followed by a constructive discussion.

The subject chosen for the February meeting was "Graphite Manufacture", and Mr. E. D. Burton presented this in a most interesting manner and described a plant which has been set up in the area. This is to be followed in March by Mr. H. Cullen, of the United Kingdom Atomic Energy Authority, whose subject will be "The Development of Calder Hall". On the Saturday following this meeting, a party of 30 members will visit the Nuclear Power Station at Annan. It is interesting to note that a number of Graduates are joining this party.

The activities of the Graduate Section will be considered by the Committee at their next meeting and it is anticipated that some guidance will be offered in respect of their programme for the 1958 - 1959 Session.

The Annual Dinner-Dance was held on 28th February and was attended by 250 members and friends, who had a most enjoyable evening. The guests included Alderman J. W. Telford, Lord Mayor of Newcastle upon Tyne; Sir William Scott; Mr. J. E. Hill, Vice-President of the Institution; Mr. W. F. S. Woodford; and Mr. Woodger, Chairman of the Tees-Side Section.

NORTHERN IRELAND REGION

Northern Ireland

Three lectures have been held during the current quarter and, despite the sometimes inclement weather, attendance interest and discussion has been maintained at a fairly high level.

In December, a Paper on "Spark Erosion Technique" was given by Mr. E. Foster, A.M.I.E.E., followed in January by "Steel at Your Service", presented by Mr. B. A. Stead. In February, a Paper on "Machining Techniques for Non-ferrous Metals" was given by Mr. S. Radcliffe, B.Sc.(Tech.), A.M.I.Mech.E., M.I.Prod.E.

NORTH MIDLANDS REGION

Regional Report

Most of the Regional activity, since the last report, has been centred round preparations for the forthcoming one-day Conference to be held in Leicester on Saturday, 7th June. The Leicester Section have formed a Sub-Committee to finalise the arrangements, and so far excellent progress has been made. The theme, "Foreign Competition — The Challenge", is a topical one and the event promises to maintain the high standard achieved in previous years.

Arrangements for the one-day Regional Conference, on 7th June, 1958, are well advanced. There are now three speakers: Mr. W. Carron, President of the A.E.U.; Mr. Kirk, of the Coventry Chamber of Commerce; and Mr. T. E. Chadwick, of the Economic Relations Department of the Foreign Office. Efforts are still being made to obtain a Government speaker.

Arrangements for entertaining the ladies include a fashion show organised by the local College of Art, and visits to various historic places.

The Conference is being held at the works of Messrs. A. A. Jones & Shipman Ltd., Leicester.

It was agreed at a Regional meeting in March that the Regional Chairman, Mr. L. Shenton; Regional Honorary Treasurer, Mr. C. H. Hodgkins; and Regional Honorary Secretary, Mr. C. N. T. Manfull, should all remain in office for a further Session.

Leicester

This year has seen the inauguration of the Leicester Section Committee Prize Award. The competition is for Students and Graduates in the Section for a Paper on a production engineering subject and the Award is to the value of 5 guineas.

The Prize for 1957 was awarded to Mr. P. Barrington, of Loughborough Technical College, for his Paper on "The Mechanisms of Chip Action and Friction in Metal Cutting". This Paper has been submitted to the Papers Committee of the Institution for consideration for publication in the Journal.

The Dinner-Dance, which was held at the Grand Hotel on 1st February, was a complete success, with an attendance of 148 members and guests, and the Committee have now decided to make it an annual event. The 1959 Dinner-Dance will be held at the Grand Hotel on 7th February.

Nottingham

Following the success of a similar meeting last year, the January meeting again gave engineering students, graduates and apprentices the opportunity to meet and question top level executives on the theme of "Engineering for Production". Four short Papers dealing with "Design for Production", "Tooling for Production", "Standards as an Aid to Production" and "Sources of New Ideas", were read by four specialists drawn from local industry.

The 19th Annual General Meeting of the Section was held in March and brought to a close the Winter Session. Mr. B. A. Green, of Ericsson Telephones Ltd., Beeston, was elected Chairman for the next Session. There was no change in the constitution of the Section Committee. The retiring Chairman, Mr. T. G. H. Middleton, in his report, said how much he had enjoyed his two years of office, and expressed his appreciation of the support he had received.

Members are now looking forward to the Summer programme, the chief item of which will be the Regional Conference to be held this year in Leicester in early June.

Peterborough

During the past quarter the Section Committee announced full details of the £5 Section Prize and Letter of Commendation which they will award annually for the best "Short Paper" submitted by a Peterborough member. In addition, the Section Chairman, Mr. W. Peck, has offered personally to award 1 guinea to every Peterborough member who has a Paper published in the Institution's Journal.

A high standard of lecture meetings has been attained during the 1957 - 1958 Session and the Annual General Meeting and one further lecture meeting have still to be held.

Final arrangements have now been made for the Chairman's Informal Dinner Party to be held in March, 1958.

NORTH WESTERN REGION

Regional Report

The Fourth Annual Dinner of the North Western Region was held on Friday, 28th February, 1958, at the Midland Hotel, Manchester. The guests for the evening were: The Lord Mayor of Manchester, Alderman Leslie Lever, J.P., M.P., LL.B.; The Rt. Hon. The Earl of Halsbury, F.R.I.C., F.Inst.P., M.I.Prod.E.; Mr. H. G. Gregory, Chairman of Council; Dr. Whitworth, M.Sc., Ph.D., Principal, Royal Technical College, Salford; Dr. Bowden, M.A., Ph.D., Principal, College of Science and Technology, Manchester. (*See Institution Notes, this issue.*)

The social function was a huge success and 120 guests, visitors and members attended. Light entertainment was included in the programme.

The Regional lecture is to be held on Monday, 28th April, 1958, entitled "Human Problems in Industry". It is to be given by Rt. Rev. Dr. Greer, Lord Bishop of Manchester, in the Great Hall of the Manchester College of Science and Technology.

Liverpool

The 1957 - 1958 Session's series of lecture meetings was completed with a successful "Brains Trust" in subjects relevant to the Session's lecture theme, "Production", the four speakers acting as a Panel.

The two Sub-Committees formed to consider "Material Utilisation" and "Papers" have submitted their Minutes to the Section Committee, who agreed to forward the Minutes of the Materials Utilisation meeting to Head Office. Mr. Pate, the Chairman of these Committees, has been asked to prepare a report based on the Minutes of the "Papers" meeting for submission to Head Office.

All next Session's lecture meetings are arranged on subjects relevant to the new Associate Membership Examination requirements and it is hoped that the Liverpool Section will have the pleasure of entertaining Mr. F. W. Cooper, Education and Technical Officer to the Institution, who will introduce the subjects as a whole at the first meeting of the Session.

Liverpool Graduate

The first lecture this quarter, "Aircraft Design" by F. Heaton, A.F.R.Ae.S., of De Havilland Ltd., was of an exceptionally high calibre, although this was the speaker's first attempt.

Another speaker, Mr. Opie, of N.I.F.E.S., presented a Paper entitled "Fuel Efficiency".

Manchester

The January lecture, entitled "Plastics Material in Engineering" was presented on 27th January by Mr. A. Clark. This was a most instructive lecture with particular reference to the use and handling of nylon.

On Monday, 17th February, Mr. Cowie, of PERA, presented a lecture entitled "Material Cutting Lubricants and Coolants". This proved to be a most informative Paper, with well-presented slides.

The lecture on Monday, 31st March, is entitled "Ceramic Cutting Tools" by A. R. Connor, Grad.I.Prod.E. This follows the Annual General Meeting, which commences at 6.30 p.m.

The Fourth Annual Dinner of the North Western Region was held at the Midland Hotel, Manchester, on 28th February, and the Manchester Section was well represented.

Manchester Graduate

So far this Session a total of four meetings have been held and five visits have been arranged.

The programme has been balanced by the inclusion of one machine tool lecture, one management lecture, one automation lecture, and a general interest lecture. The attendance at these meetings has been around the 30 mark, about half being visitors.

During the next Session there are likely to be six vacancies upon the Committee, caused by members transferring to Associate Membership during the year.

Preston

The Annual General Meeting of the Section was held at Blackburn in March, when it was reported that during the past year, the total membership of the Section increased by approximately 6%, half the increase being in the Associate Member grade. This compares with approximately 1½% for the Institution as a whole.

Attendances at lecture meetings averaged 74, indicating an increased interest in Section activities.

Continuing the Committee's policy of taking lectures to the remoter parts of the Section, a joint meeting was arranged with the Barrow and District Productivity Committee at Barrow.

Mr. J. A. Westall, M.I.Prod.E., a retiring member of the Section Committee, did not seek re-election due to recent ill-health. Mr. Westall is a Past Chairman of the Section and has been a very active member of the Preston Section from its inception. His work on Section activities has been invaluable and his loyalty has been an inspiration to his colleagues.

SCOTLAND REGION

Dundee

February, 1958, will long be remembered by the Dundee Section as the month in which a visit was received from the President, Lord Halsbury; and the Secretary, Mr. Woodford. It was the first visit by a President in office since the formation of the Section in 1949.

The Presidential party spent a busy 12-hour day in this most northerly Section. Arriving off the night train, they visited the Technical College and Veeder Root Ltd. during the morning and admired the panoramic view of Dundee and the Tay Estuary from the Law.

At lunch the party was joined by the Lord Provost, and afternoon visits were made to Wm. R. Stewart & Sons and the National Cash Register Co.

Section members and representatives of local engineering industry were welcomed by Lord Halsbury at dinner, and the culmination of the day was the delivery of his address, "Technical Training and Professional Status". The address was preceded by the presentation of medals, prizes and Higher National Certificates in Production Engineering to technical college students. At 9.30 p.m., after a long and successful day, Lord Halsbury set out for Edinburgh by the long land route *via* Perth.

The final lecture of the season was given by Mr. F. L. Morton, of Messrs. Kalamazoo Ltd. It was a lecture and demonstration on methods of material control progress, machine loading, etc. The interest shown was demonstrated by the time the audience lingered for more information long after the normal finishing time.

Edinburgh

Two very enjoyable events took place in Edinburgh in the last quarter. The first was the visit of the National President to the capital of Scotland, where, after meeting the Lord Provost of Edinburgh and signing the distinguished visitors' book, he was shown around the works of the North British Rubber Company. Mr. P. H. Lee, the Section Chairman, acted as host.

A Luncheon was held at the North British Hotel, where members enjoyed an informal opportunity of meeting the President and Secretary of the Institution.

After a visit to Brown Bros. Ltd. works to see the manufacture of catapults and hydraulic steering gears, where Mr. Betts Brown, the Regional Chairman, acted as host, there was a reception where managing directors and works managers of local industry welcomed the President and Secretary.

Finally, the Presidential Address was presented to a large audience of members, managing directors, production engineers and friends.

The second event during the quarter was a joint meeting in the North British Hotel with the Institute of Materials Handling to hear an address entitled "The Case for Materials Handling", given by the Section's representative on the Materials Handling Group, Mr. F. Eccersley, who handled the meeting very well. When it came to question time, it was made clear that he is a master in his subject.

SOUTHERN REGION

Oxford

In the period January - March, 1958, the finalisation of the Oxford Section programme will complete the general activity for the Institution year.

The lecture Session for the year 1957 - 1958 will terminate in a Members' Discussion Meeting on March 18th, following the Annual General Meeting of the Section.

The highlight of the year's activity was the February meeting, addressed by the Institution's President, Lord Halsbury, who spoke on "Technical Training and Professional Status".

The February meeting formed the final instalment of a series of meetings arranged during the year around the theme "Development of Modern Manufacturing Techniques", which was a follow-on from the previous programme based on the development of materials to meet the need of modern production trends.

The 1957 - 1958 lecture Session was the third and final section of a three-year lecture plan to follow the theme of "Automation", following the 1955 National Conference.

Reading

The Section had the pleasure of listening to a most enjoyable lecture given by Mr. H. Mott, Committee member, on "Materials Handling". This Paper is one that is highly recommended for any Section.

An improved attendance is reported compared with last Session, at all our lectures.

A joint meeting with the local Productivity Association was held in February. The Institution supplied the Chairman and lecturer and the meeting proved to be very successful. This is the second year a joint meeting has been arranged with the Productivity Association.

A Summer works visit has been arranged for 19th June. Details will be circulated to the Section nearer the date.

SOUTH EASTERN REGION

Regional Report

A number of Papers have now been submitted for the South Eastern Region Graduate Prize Competition, and these are being considered by a panel of assessors.

A Regional meeting will be held on 24th April next, when Professor Postan will present a Paper on "The Engineering Industry Since the War".

London

Lecture meetings have constituted the main activity during this quarter and in spite of the hazards of the weather, have been well supported.

Topics covered have been varied and have included lectures on "A New Approach to Production Control" and "Research on Modern Metal Cutting Techniques". There are two more lectures to come during the season's programme. Arrangements are well in hand for the coming season's activities and it is hoped that the subjects will prove as interesting.

The Annual Stag Dinner held on Wednesday, 12th February, was most successful, and was attended by the President of the Institution, Lord Halsbury.

The Section Committee's elections take place shortly. Six members of the Committee have retired, but have signified their willingness to stand for re-election.

Luton Graduate

The last function in 1957 was a lecture given in St. Albans, by Mr. F. C. Woods. His subject was "Contour Etching" as a method of metal removal used in the aircraft industry.

1958 was to have commenced with a visit to Armco Ltd.'s unique factory at Letchworth, but this unfortunately had to be cancelled.

The Graduate Evening this year brought forth only one Paper and so was replaced by a film show. It was agreed that the film on "Ferguson Tractor Manufacture" was the best presentation so far seen by the members.

Forthcoming events include a visit to George Kent Ltd., Luton, and the possibility of holding a joint car "Treasure Hunt" with the Senior Section.

Rochester

Progress has been normal during the Session and the Annual General Meeting is due to be held in April.

At a recent Committee meeting it was decided to carry out an experiment, which, if successful, would increase attendance at monthly lecture meetings. The idea centres around offering a selected list of subjects to the major companies in the area, asking them to select one, and the Section would then make all arrangements for a Paper on that subject to be presented. The company concerned would be required to guarantee a quota attendance from its production and associated personnel. Up to four companies may be approached for next season's arrangements and any success achieved will be notified to Head Office as other Sections may then decide to give the idea a trial.

South Essex

The first meeting of 1958 was held at the Mid-Essex Technical College, Chelmsford, on Wednesday, 15th January, when 30 members and friends attended to hear Mr. E. S. Carden, Manager, Lecturing and Film Department, The British Tabulating Machine Co. Ltd., present a Paper, "Office Mechanisation — Today and Tomorrow".

On Wednesday, 12th February, a meeting was held at the Ilford Club, when Mr. G. W. Bentall, of the Signal Engineer's Department, British Railways, presented a Paper on "Automatic Railway Signalling in Relation to Railway Electrification".

The Section Annual General Meeting is to be held at the Mid-Essex Technical College, Chelmsford, on Wednesday, 12th March, after which two films will be shown. Mr. F. W. Cooper, Education and Technical Officer of the Institution, will be present to meet members of the Section and to answer questions.

SOUTH WESTERN REGION

Gloucester

During the last quarter the Section has held two very interesting lectures. The first, a Graduate lecture held jointly with the Engineering Society of the North Gloucestershire Technical College and entitled "Gear Hobbing", covered the theory behind the Pfauter system of gear production. After the theory came the features built into the Pfauter machines, such as the differential shaft for helical and diagonal hobbing. The main film was followed by a film showing some of the mechanical handling of components on Pfauter machines. A lively discussion followed.

The second lecture was held jointly with the Gloucester Engineering Society and covered "Radio-active Isotopes". It proved to be very interesting, with a practical demonstration of the use of isotopes and some good slides and diagrams showing other ways the speaker had used isotopes and the results that were obtained.

Western

The Section was very honoured to receive Lord Hives to present the 1957 Viscount Nuffield Paper, and are glad to report that there was an excellent audience. It was unfortunate that time did not permit of more discussion, particularly as there was present a very good cross-section of the educational authorities and industry from this part of the country. It was obvious that the lecture was a success, as the Press reports in most of the national papers were most encouraging.

The Section's Materials Handling Group has got away to a good start and has been fortunate in interesting several experts in the district, who at the moment are not members of the Institution.

The Materials Utilisation Sub-Committee has been receiving special attention and here again is it anticipated that some good case studies will result.

The lecture programme for 1958 - 1959 is now being formulated and includes the annual meeting with the Royal Aeronautical Society, and also a joint lecture with the Bristol and Bath Productivity Council.

WALES REGION

Regional Report

The Welsh Region has been active during the Winter Session with a very attractive lecture programme. Both Sections report excellent meetings with good support.

An informal dinner was held in the Wyndham Hotel, Bridgend, on 21st February, when members from both Cardiff and Swansea Section Committees were invited. The Chair was taken by the Regional Chairman, Mr. W. H. Bowman, and a very enjoyable evening was spent by all.

The dinner was preceded by a Regional Committee meeting, during which the final arrangements for the one-day Conference to be held on 29th April, 1958, at Messrs. B.P. Refinery (Llandarcy) Ltd., were discussed and agreed upon. This event is anticipated in the Region with great expectations and confidence.

A Regional works visit has been arranged for members and their ladies on 24th March, 1958, to Messrs. Hoover (Washing Machines) Ltd., Merthyr Tydfil.

Cardiff

During the past quarter lectures have been very well attended, the average attendance being over 80. A particularly successful lecture was given by Mr. A. J. Nicholas, O.B.E., M.I.E.E., on "The New Industrial Pattern of South Wales" and resulted in the highest attendance of this Session (*see page* 339 *of this Journal*).

Members of the Cardiff and Swansea Section Committees were invited to attend the Regional Committee meeting on 21st February, at Bridgend, when a very valuable interchange of viewpoints on Institution matters was made. Discussions also took place on the forthcoming Regional factory visit on 26th March to Messrs. Hoover (Washing Machines) Ltd., Merthyr Tydfil. In addition, a progress report was given on the one-day Conference to be held at the National Oil Refineries, Llandarcy, on 29th April, 1958. This Conference will be attended by the President of the Institution, The Rt. Hon. The Earl of Halsbury, F.R.I.C., F.Inst.P., M.I.Prod.E.

Swansea

It is reported with regret that the Section Chairman, Capt. V. J. Sankey, R.N.(Retd.), has been indisposed for the past six weeks, and all members will join in wishing him a speedy and complete recovery.

The Section's successful lecture programme comes to an end on 14th March, 1958, and a film show will be arranged for Friday, 18th April, 1958, to complete the Winter Session. A preview of films in connection with the Materials Handling Group within the Section is arranged for Section Committee members on 31st March, 1958, at 7 p.m. at the Technical College, Swansea. Members of the Committee visited the Technical College, Swansea, on 12th December, 1957, and enjoyed a most interesting tour of the College facilities for both civil and mechanical engineering.

SECTIONS OUTSIDE THE UNITED KINGDOM

Bombay

At the Section meeting held on 14th January, a film show was given by Messrs. Voltas Ltd. on "Absolute Measurement" and "Optical Jig Boring Machines at Work". This proved to be very popular and nearly 150 members and visitors were present.

On 11th February, Mr. I. Mann, M.I.Prod.E., read a very interesting Paper on "Abrasives". The lucid and thorough manner in which Mr. Mann covered his subject was greatly appreciated by over 50 members who attended this meeting.

A most interesting Paper on "Mass Production of Metre Gauge Open Wagons in Bombay City", is to be presented on 11th March by the Section Chairman, Mr. C. H. De Sousa. A visit has been arranged to Messrs. Hind Razor & Blade Co. Priv. Ltd. on 22nd March, which it is hoped will prove of value to Graduates and Students of the Section.

Calcutta

The Section Annual Dinner was held on 31st January, and was attended by a large number of members, with their guests. This was a most successful occasion.

A works visit was arranged on 22nd January to The Jay Engineering Works Ltd., but unfortunately had to be cancelled as a mark of respect to the late Abul Kalam Azad, Education Minister to the Government of India, whose death was announced on that day.

The Annual General Meeting was held on 27th March, 1958, when the Section Officers and the Committee for the year 1958 - 1959 were elected. Two Section Committee meetings were held during January and February, and two more will be held in March.

Melbourne

There have been no monthly meetings of the Melbourne Section during this last quarter, as this is the normal period of recess.

The Committee have been active over this period and have arranged an interesting programme of lectures and works visits for 1958.

In November, a Productivity Group was formed from members, to discuss ways and means of assisting productivity in Australia. This Group have met twice and are now formulating a plan for 1958.

Melbourne Graduate

The Committee has now finalised the 1958 programme and a most interesting lecture and question night have been included in the programme. The Committee hope that these meetings will prove successful, as it is thought that general discussion on production problems will be of considerable benefit in the development of Graduates and Students.

Apart from Committee meetings to finalise the programme, the Section has been in recess during this quarter.

Sydney

The first lecture in the year's programme was given at the March meeting by Dr. Arthur Denning, D.Sc., Dip.Ed., A.S.T.C., F.R.S.A., New South Wales Director of Technical Education. Dr. Denning, who has recently returned from an overseas tour, spoke on "Industrial North America Today", and the audience were given interesting aspects of American life and industry, illustrated by coloured slides, as seen through the eyes of an able educationist.

It was heartening to see a large-than-average attendance for the first meeting.

The Papers Sub-Committee has produced an excellent lecture programme, and a visit to inspect the Snowy Mountains Hydro Electric Scheme is being organised for the latter part of the year.

Mr. E. G. Bishop, Member, a Past Chairman of Sydney Section, advises that he is planning to visit Headquarters on his forthcoming trip to the United Kingdom.

JOURNAL BINDERS

Strongly-made binders for the Institution Journal, each holding 12 issues, may be obtained from Head Office, 10 Chesterfield Street, London, W.1, price 10/6 each, including postage.

RESEARCH PUBLICATIONS

The Institution is advised by PERA that Dr. G. Schlesinger's book on "Accuracy in Machine Tools: How to Measure and Maintain It" is now out of print and cannot, therefore, be supplied. The following I.Prod.E. publication is, however, still obtainable from PERA at "Staveley Lodge" Melton Mowbray, Leicestershire.

"Practical Drilling Tests" by D. F. Galloway and I. S. Morton. Price 21s.

institution notes

BRITISH TRANSPORT COMMISSION — AWARDS FOR EXAMINATION SUCCESSES

The Institution of Production Engineers has been informed by the Director of Training and Education for the British Transport Commission that the Institution has been included in the Commissions Awards for Examination Successes scheme.

The qualifications to be recognised, and the awards to be paid for them, are as follows :

On admission as Graduate of the Institution after passing the requisite parts of the Associate Membership Examination — increment of £25 per annum.

On admission to the grade of Associate Member, after passing the whole of the Associate Membership Examination—additional increment of £25 per annum.

Those who have gained the qualifications since 1st January, 1953, will be eligible for the award, and the increment will be payable from 1st January, 1958. Those who gain the qualifications after 1st January, 1958, will be entitled to the increment from the date on which they qualify.

READING SECTION DINNER

It is reported by the Reading Section that over 90 members and their guests attended their highly successful Annual Dinner at Grosvenor House, Caversham, Reading, on 18th April last. Members came from as far afield as Bristol, Newbury, Staines, Portsmouth and Basingstoke, as well as from local areas.

Mr. A. Waterhouse, who proposed the toast of "The Guests", made special mention of the part Mr. R. F. Newman, C.B.E., the Guest of Honour, had played in encouraging the young engineer in his training. Mr. Newman, in his reply, stressed the importance of the trained production engineer in industry.

Mr. H. A. Richardson, Chairman of the Reading Section, said that he was now handing over the Chairmanship to Mr. H. P. Mott, and that he was confident the growth of membership and activities of the Section would continue to develop in serving the needs of production engineering.

An amusing feature of the evening was a special toast list and menu card designed by a member of the Section.

NORTH WESTERN REGION ANNUAL DINNER

The Fourth Annual Dinner of the North Western Region was held on 28th February last, at the Midland Hotel, Manchester, and was as usual a most enjoyable and successful occasion.

In this photograph the President of the Institution, Lord Halsbury (right), is seen with (from left) Mr. J. P. Speakman, Regional Honorary Secretary; Mr. J. H. Winskill, Regional Chairman; Mr. R. H. S. Turner; Dr. B. V. Bowden, Principal, Manchester College of Science and Technology; and Dr. Whitworth, Principal, Royal Technical College, Salford.

In this photograph, taken at the Reading Section Dinner, are (back row, from left) Committee members Major Hosking and Messrs. Reid, Christy, Wilson, Mark, Ralph, Waterhouse, Daughtrey and Smallbone. (Seated, second from left) Mr. Woodford, Institution Secretary; Mr. Newman; Mr. Richardson, Section Chairman; and Mr. Mott, Chairman-Elect.

news of members

Mr. E. H. Y. Burden, Member, has been appointed General Manager of the Amar Tool & Gauge Co. Ltd., which is one of the Plessey Group of Companies, at Chadwell Heath, Essex.

Mr. R. C. Fenton, Member, has left the Birmingham Office of Alfred Herbert Ltd., and is now situated at the Head Works at Coventry.

Mr. J. A. Grainger, Member, has relinquished his appointment as Development Engineer with British Light Steel Pressings Ltd., and has now gone into partnership with Mr. Henry W. Lawton, Member, in a consultancy business, European Industrial Consultants Ltd., Birmingham. At the same time, Mr. Grainger has been appointed a Director of Henry W. Lawton Ltd., Oldbury, Birmingham.

Mr. R. W. Harris, Member, has relinquished his position as Works Manager of Bryce Berger Ltd., and has now taken up an appointment as Director and General Manager with Aircraft Steel Structures Ltd., Park Royal.

Mr. L. L. Chadderton, Associate Member, is now a Production Engineer with the National Electrical and Engineering Co. Ltd., at the Kawharawhara factory, Wellington, New Zealand.

Mr. J. Harrison, Associate Member, is taking up an appointment as Lecturer in Mechanical Engineering at the Mid-Essex Technical College and School of Art, Chelmsford.

Mr. F. E. Langdon, Associate Member, has recently relinquished his appointment with The Metal Box Co. Ltd., Engineering Division, and is now a Senior Plant Designer with Combined Technical Services Ltd., Egham, Surrey.

Mr. W. Long, Associate Member, has relinquished his position as Production Development Engineer with Hawker Aircraft Ltd., Kingston-on-Thames, and has taken up a position of District Manager in the new Bristol office of Associated British Machine Tool Makers Ltd.

Mr. H. C. R. Pegler, Associate Member, has been appointed President of the Gloucestershire Engineering Society. He is a member of the Gloucester Section of the Institution, and also Vice-Chairman of the Ribston Hall Parent-Teachers' Association. Mr. Pegler has been associated with the Gloucestershire Engineering Society since 1927 and has, in association with Mr. P. S. Fowler, another prominent local engineer, been for a number of years a member of the Engineering Advisory Committee representing the Gloucestershire Engineering Society at the Gloucester Technical College.

Mr. C. H. John, Graduate, has relinquished his appointment as Planning Engineer with D. Napier & Son Ltd., and has taken up a position as Estimator and Process Planner with the General Electric Company (U.W. Unit) Perivale, Middlesex.

Mr. A. J. Wale, Graduate, has recently taken up an appointment as Chief Work Study Engineer with Salisbury Transmission Ltd., Birmingham.

DIARY FOR 1958

27th - 31st August ...	**Annual Summer School,** Ashorne Hill, Warwickshire. (See Supplement to this Journal.)
13th 14th 15th October	**Materials Handling Convention,** Brighton.
29th October	**Annual Dinner of the Institution,** Dorchester Hotel, London.
11th December	**The 1958 Sir Alfred Herbert Paper,** to be presented at the Royal Institution, London. Speaker: **Sir Cecil Weir,** Past President of the Institution. Subject: **"The European Common Market — Its Origins and Implications".**

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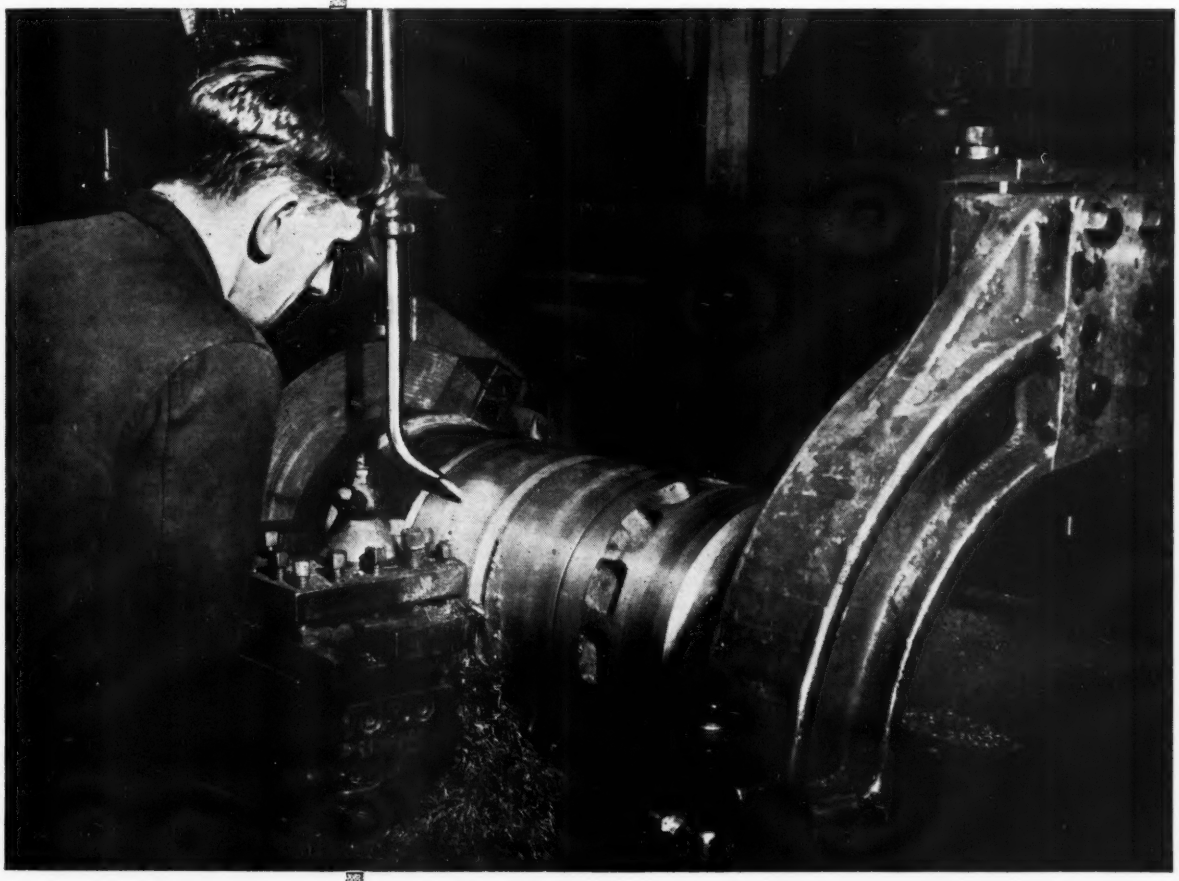

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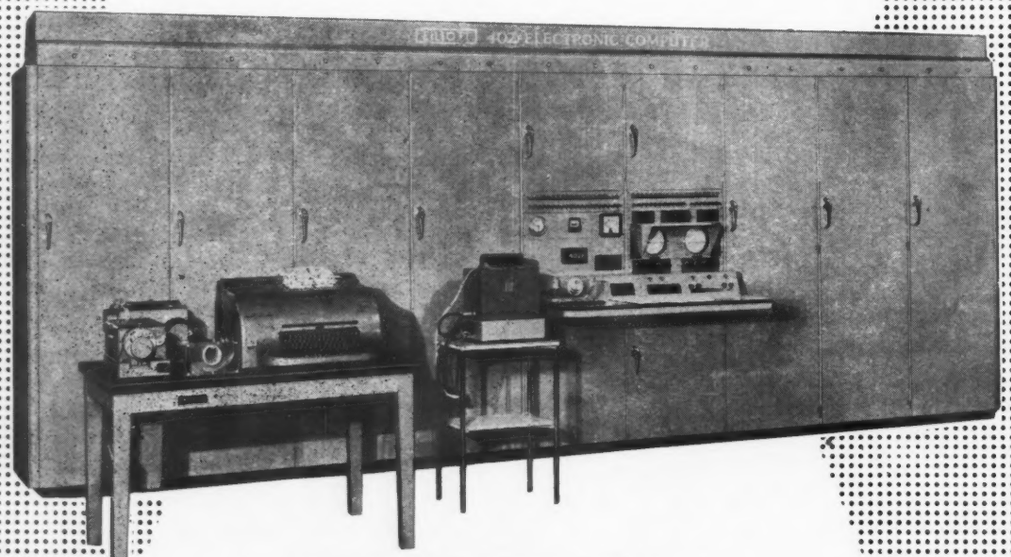

ELLIOTT

FLOATING POINT ELECTRONIC DIGITAL COMPUTER

402F

The Leica camera manufacturers — Ernst Leitz GmbH — have installed an Elliott 402F in their Wetzlar works for use in the study of lens design. With built-in floating point facilities for ease of programming, the 402F is ideally suited for the investigation and solution of all types of research, development and design problems involving complex mathematical analysis.

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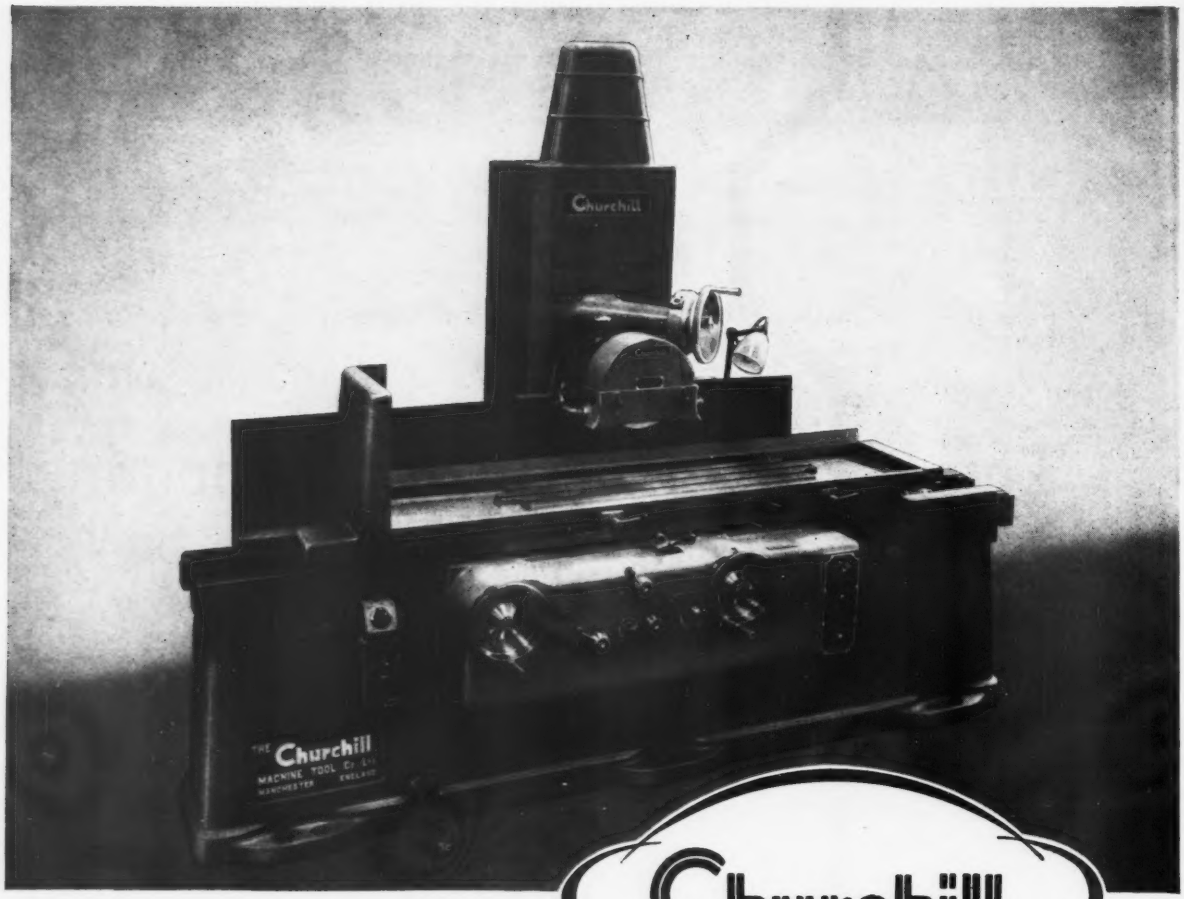

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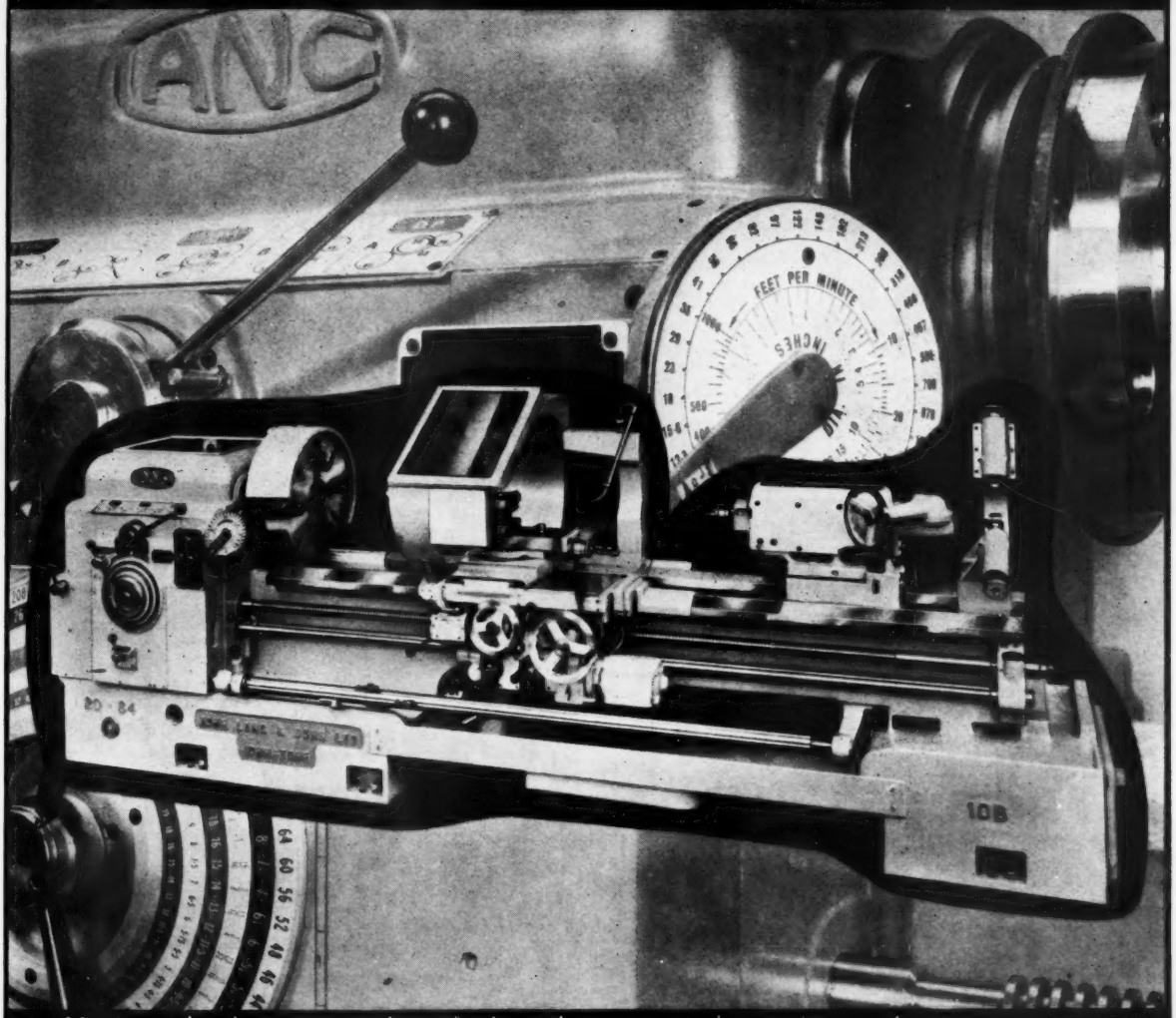

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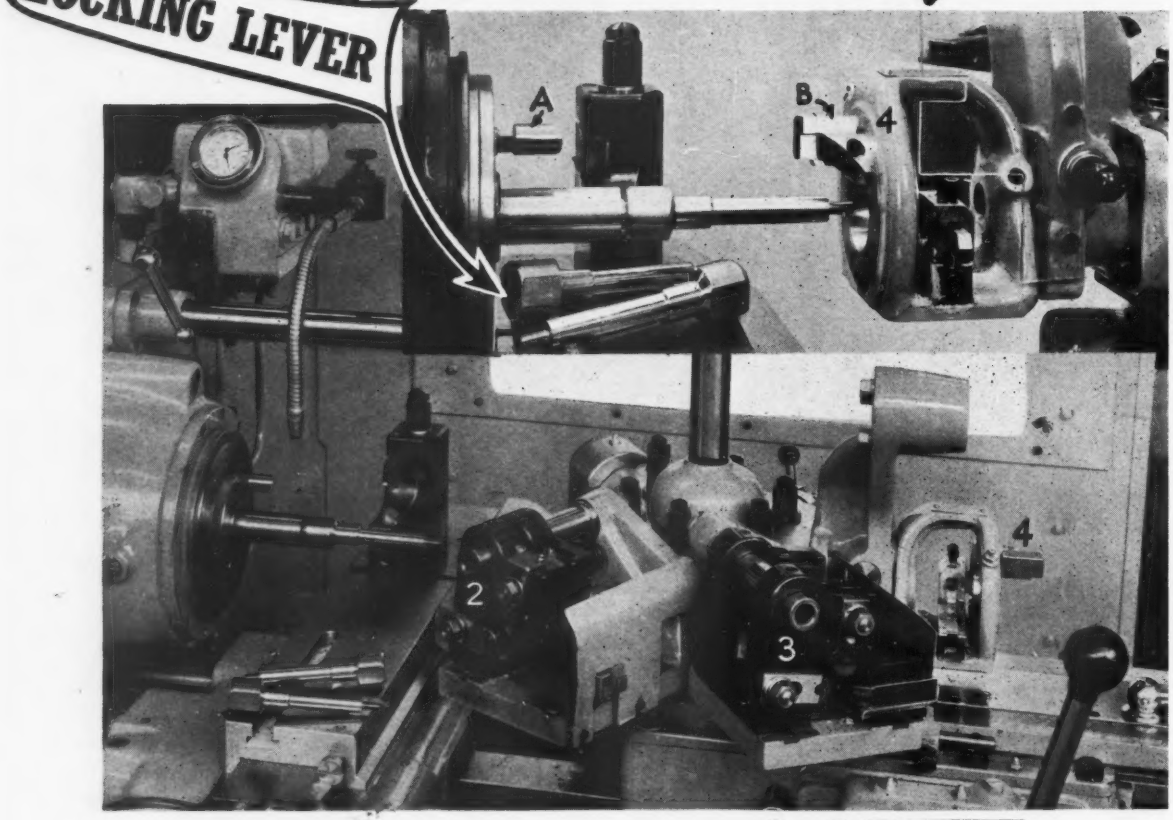

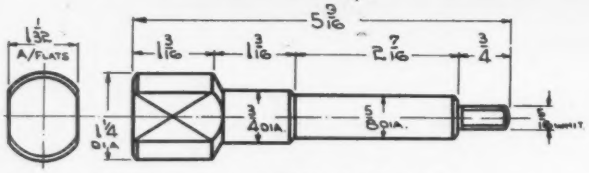

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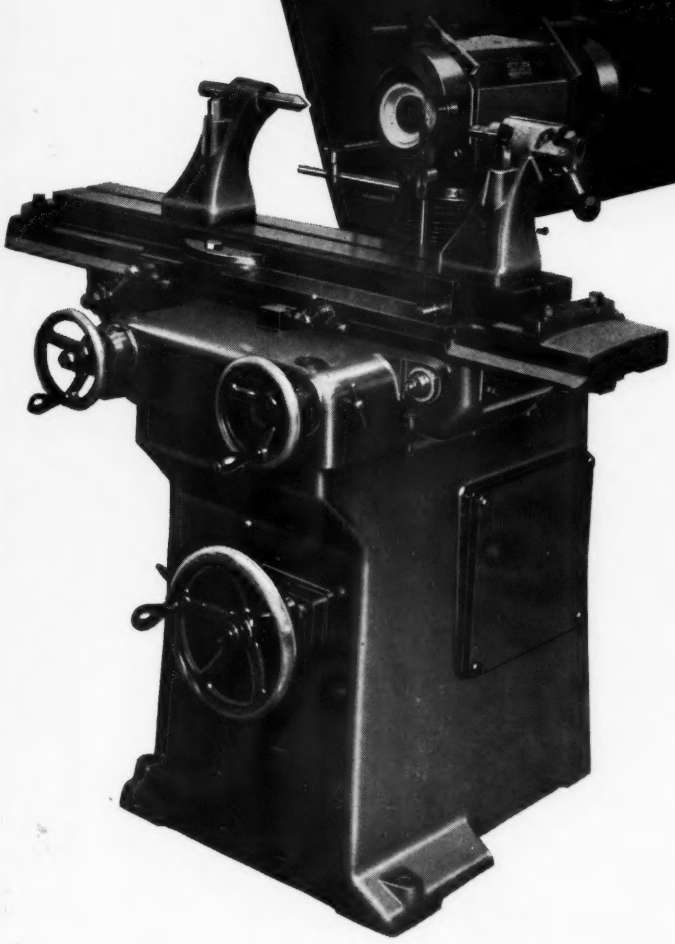

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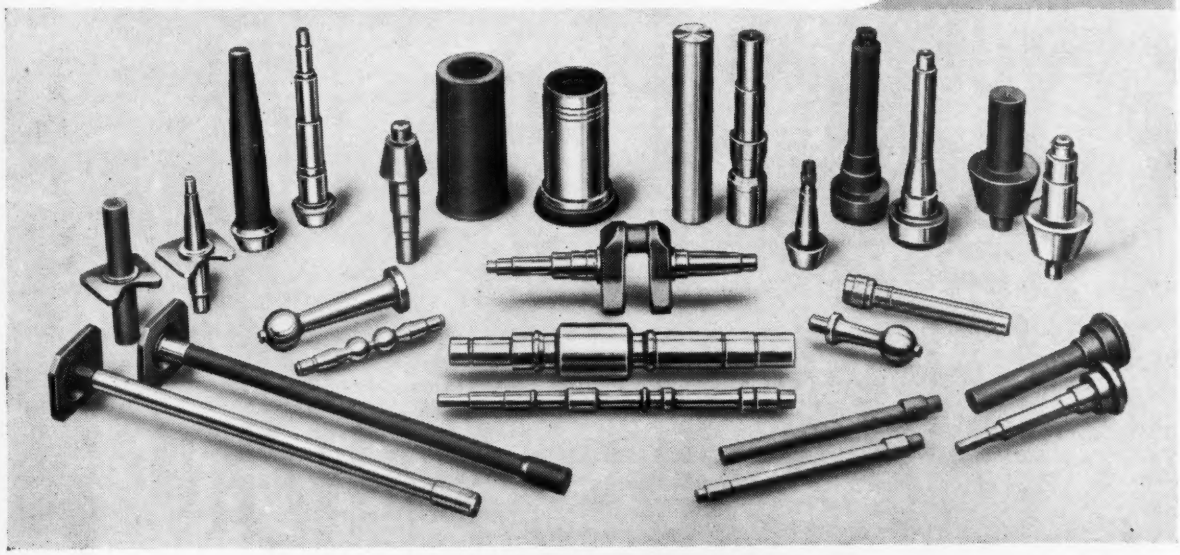

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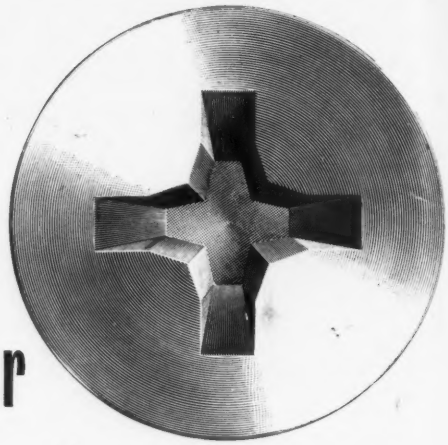

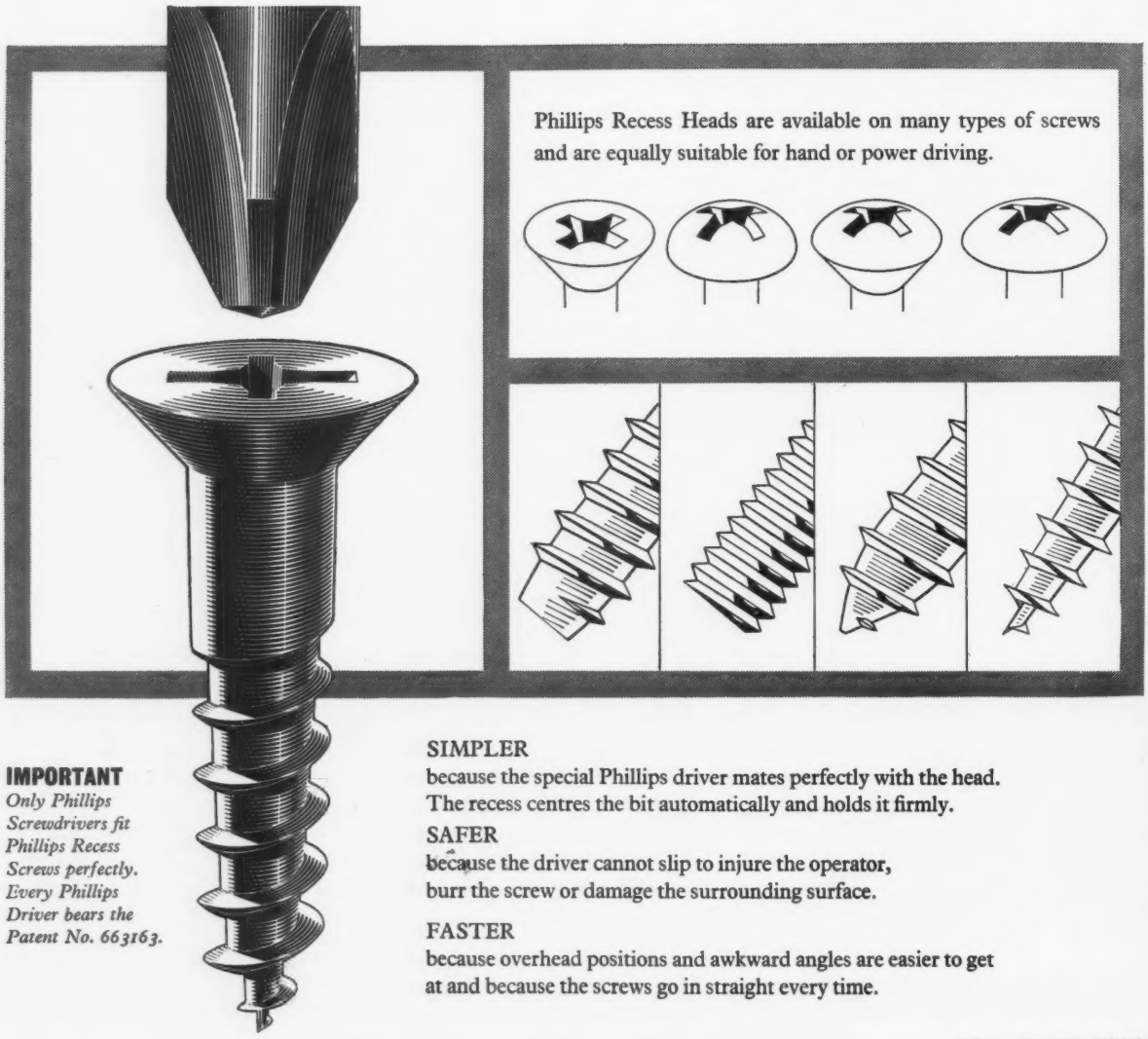

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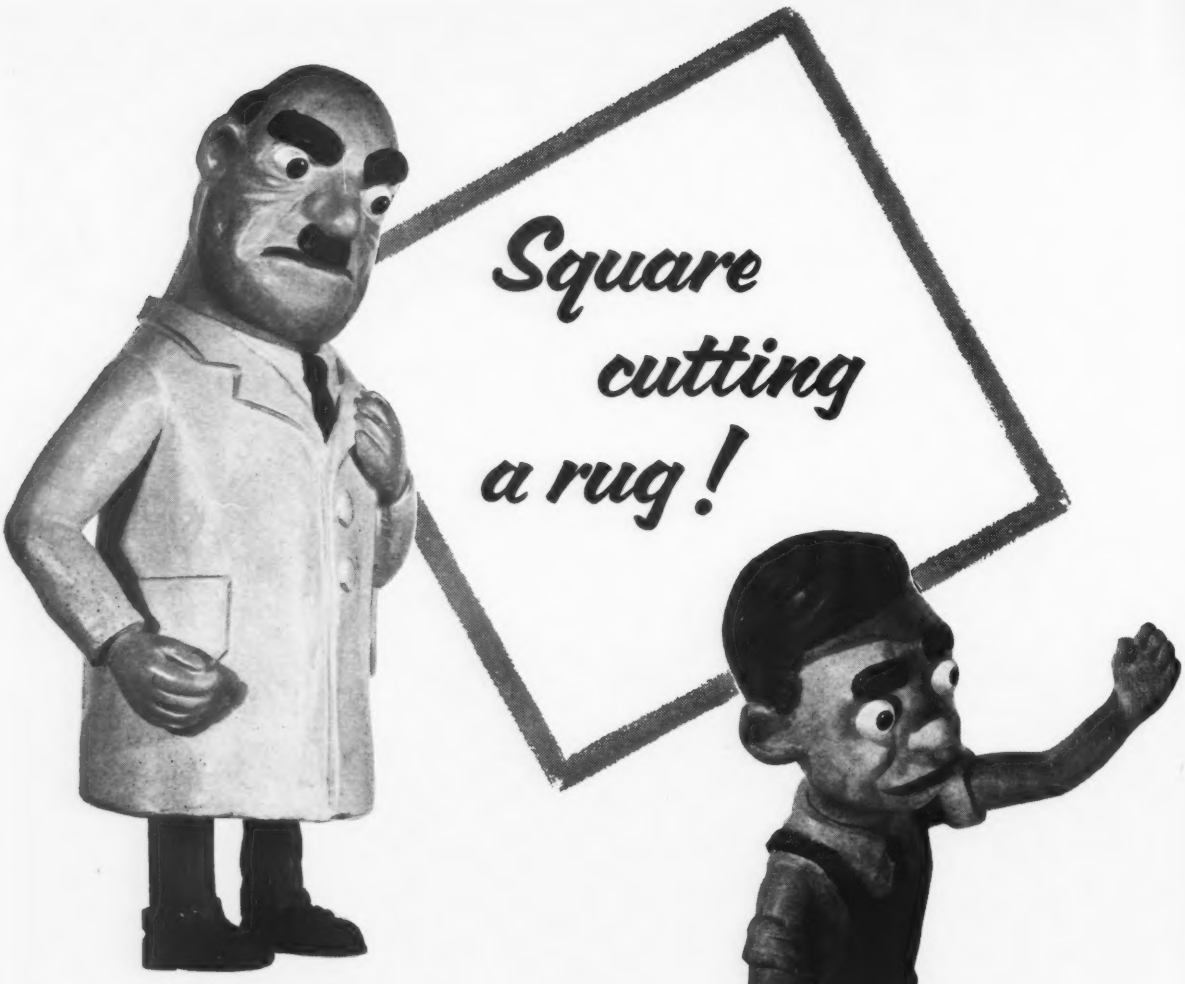

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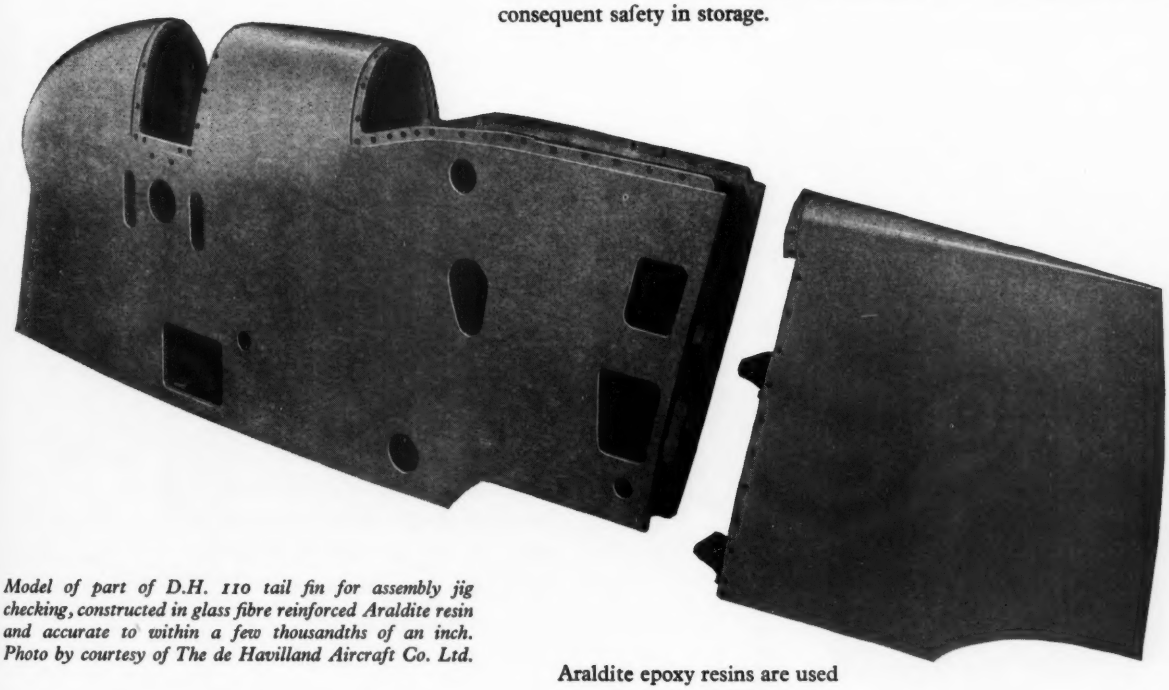

Model of part of D.H. 110 tail fin for assembly jig checking, constructed in glass fibre reinforced Araldite resin and accurate to within a few thousandths of an inch. Photo by courtesy of The de Havilland Aircraft Co. Ltd.

The recommended techniques are simple and easily acquired. Full details and practical assistance are available upon request. May we send you a copy of our new publication on Araldite for tools, jigs and fixtures?

Araldite epoxy resins are used

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- **for casting high grade solid electrical insulation**
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- **for producing glass fibre laminates**
- **for making patterns, models, jigs and tools**
- **as fillers for sheet metal work**
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Araldite *epoxy resins*

Araldite is a registered trade name

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AP327

That's the ticket

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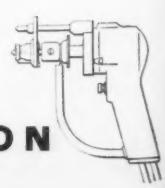

STUD WELDING STEPS UP PRODUCTION

are you informed about *Hylite* TITANIUM ALLOYS?

Hylite **is** the name covering a range of Titanium alloys manufactured by Jessop, whose long research and experience have resulted in their producing the largest Titanium ingots in Europe. Hylite is available in seven qualities.

Hylite **has** a high strength-to-weight ratio and excellent corrosion resistance. Hylite alloys are reasonably free from embrittlement and may be forged, cold-worked, welded and machined.

HYLITE 10 TITANIUM ALLOY. Commercially pure titanium, supplied to D.T.D. specifications 5013 and 5033. Resistance to corrosion with maximum formability and weldability where strength is not critical.

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Commercially pure titanium (soft grade)	19.0	27.0	30.0	125
Commercially pure titanium (hard grade)	23.0	34.0	25.0	160
5% Al., 2½% Sn.	46.0	56.0	18.0	270
2% Mn., 2% Al.	36.0	44.0	20.0	240
4% Mn., 4% Al.	58.0	62.0	18.0	300
6% Al., 4% V.	58.0	63.0	22.0	300
Complex Al. alloy	64.0	72.0	15.0	360

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Application of Research	Plant and Equipment Policy
Materials Handling	Designing for Production
Control of Quality	Tooling and Measurement
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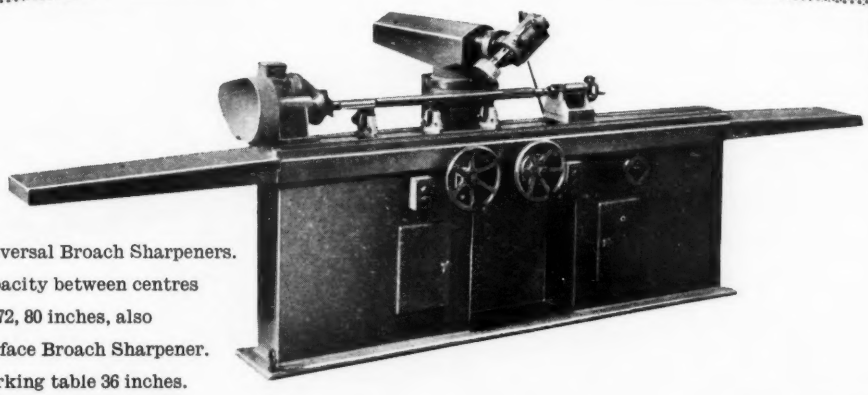

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Capacity between centres
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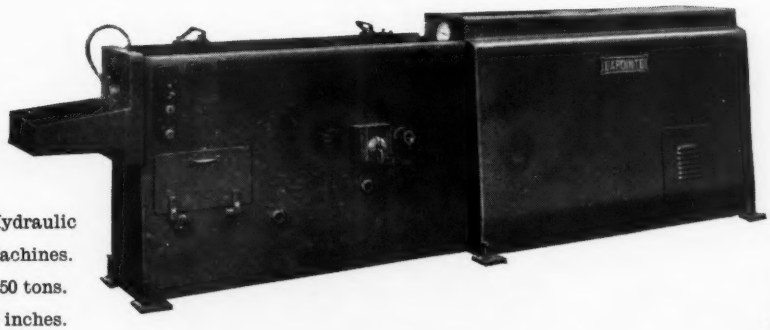
Working table 36 inches.



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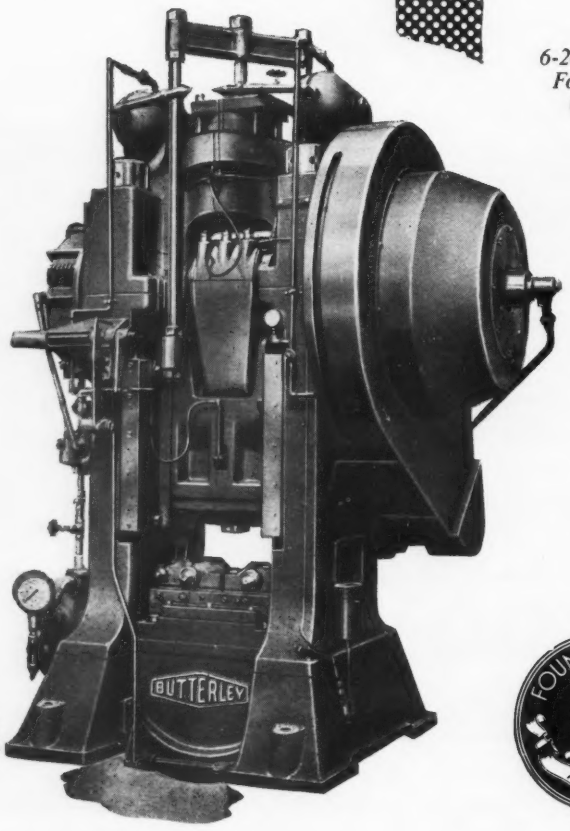

6-26 High-speed Forging Press (120 tons)

Full details of Butterley Sheet Metal Machinery supplied on request . . .

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SM 12

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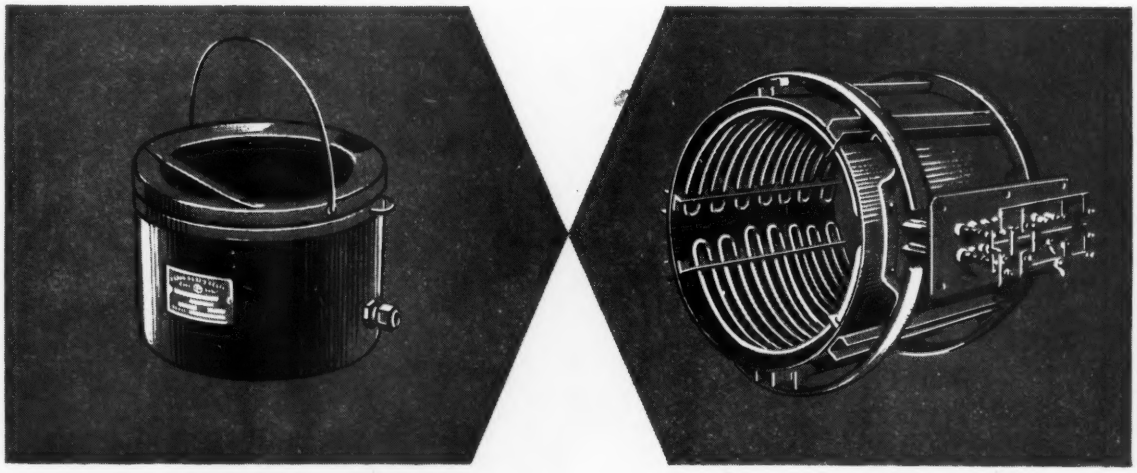

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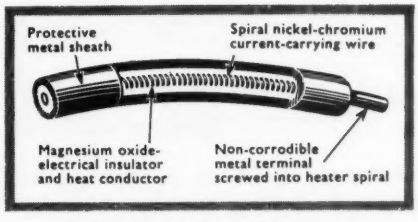
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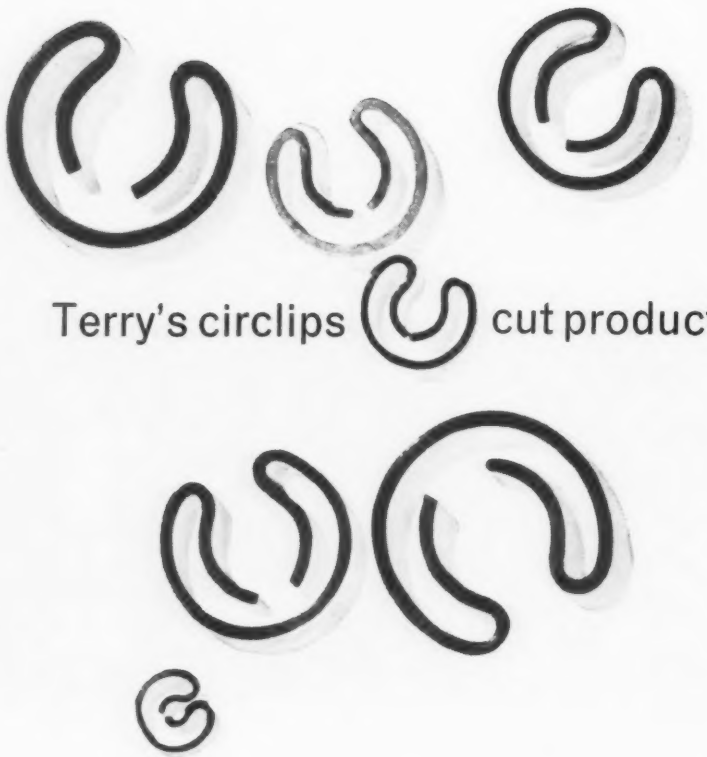

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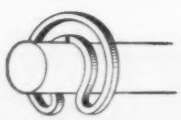

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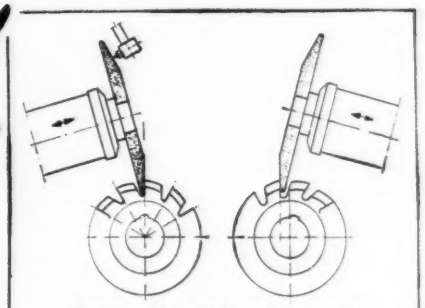

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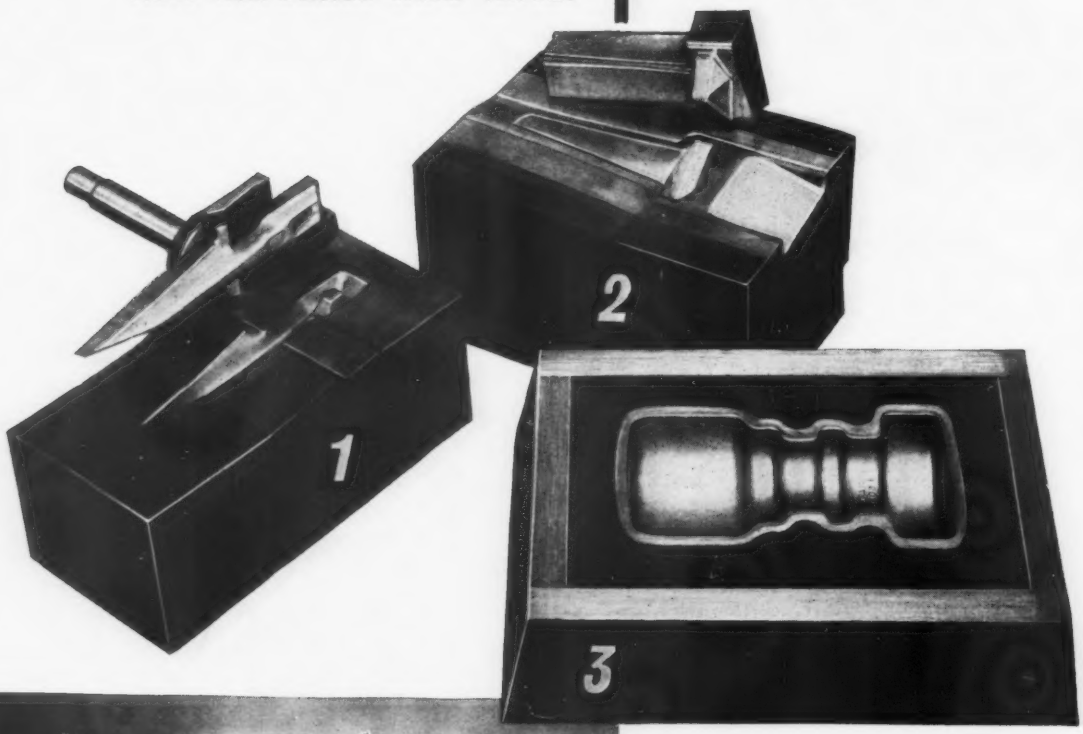

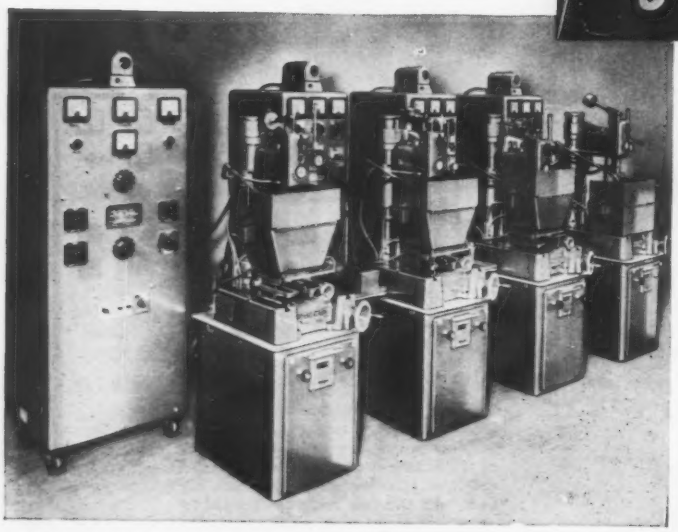

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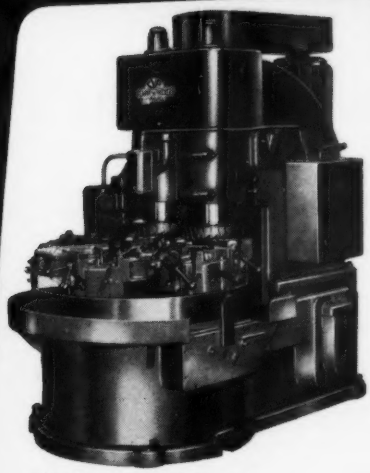
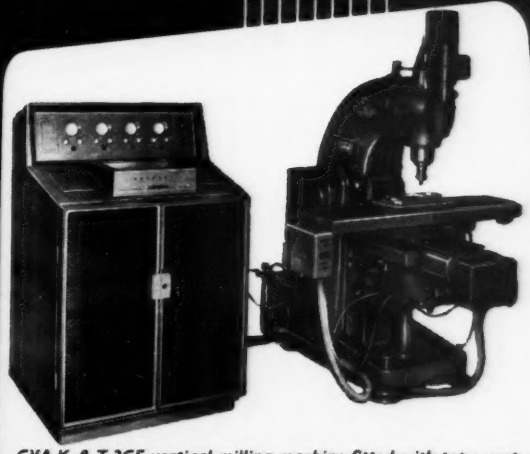


CVA K & T vertical 2-spindle rotary table milling machine.



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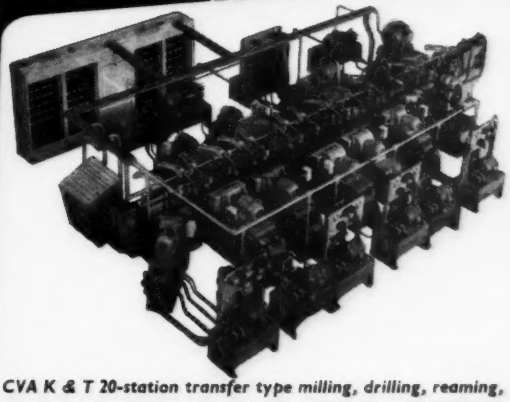

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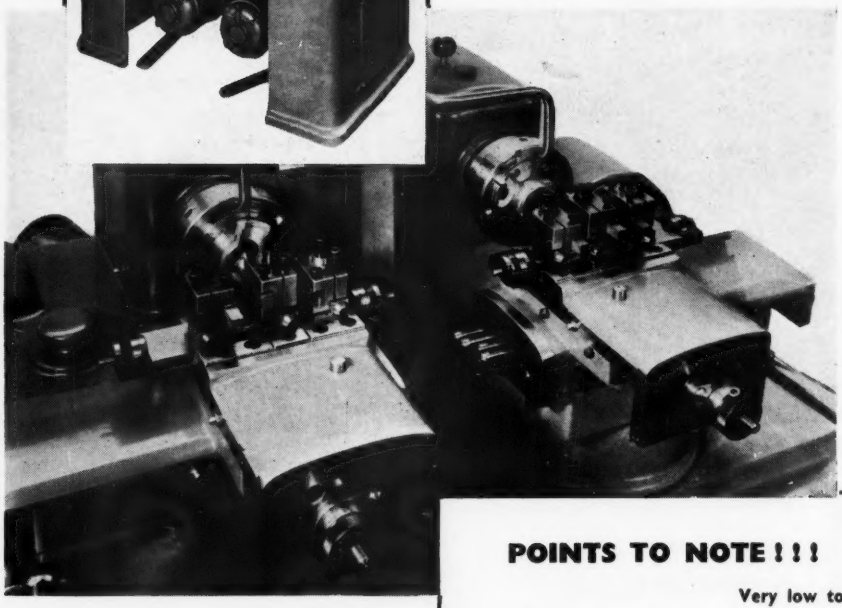

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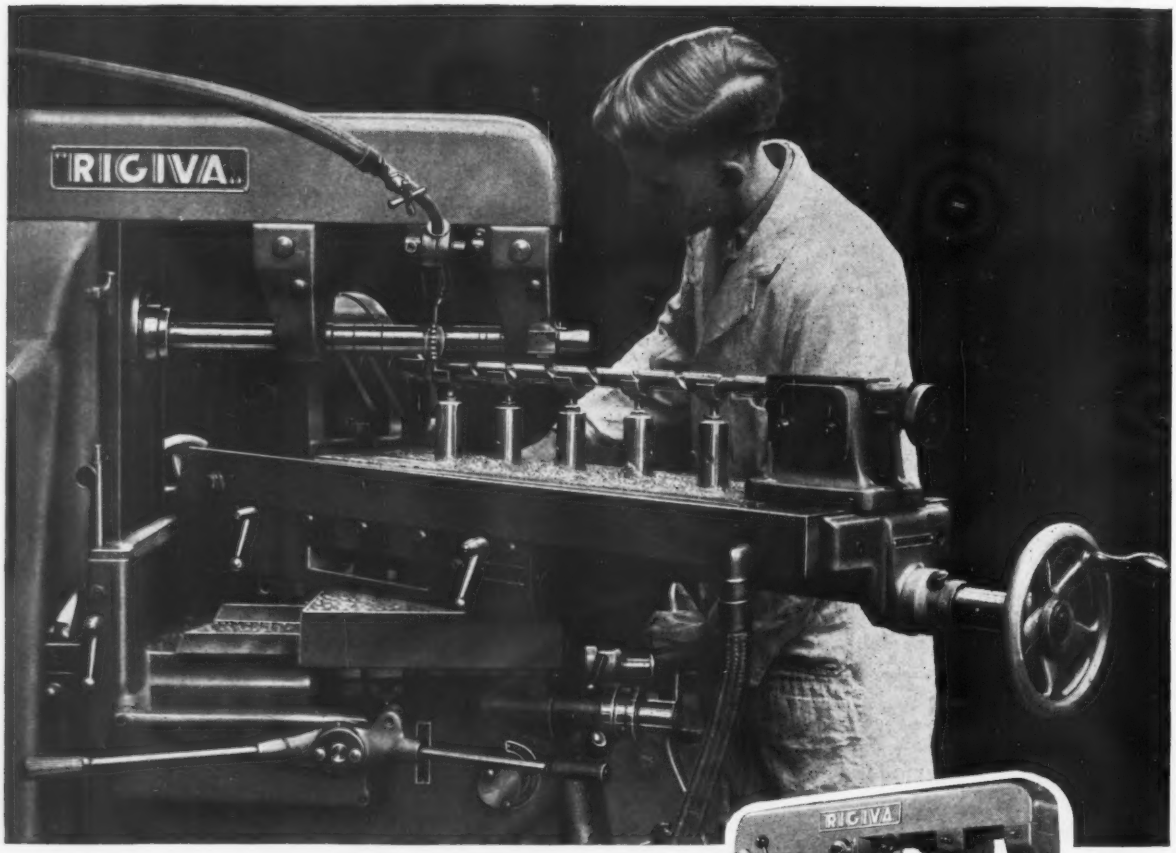

The U.B. at work on a traverse shaft for Silent Machine and Engineering Co.

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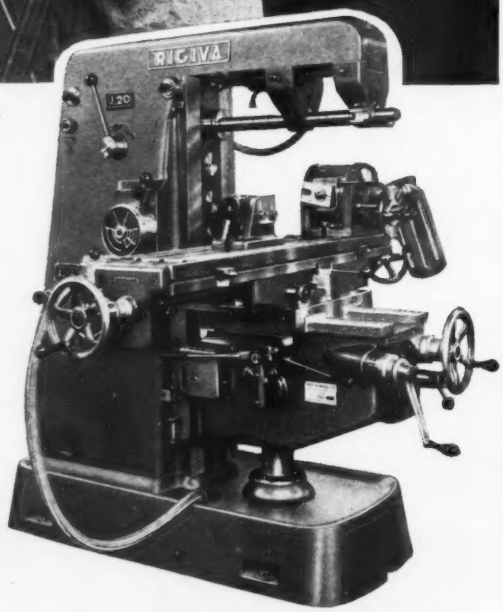

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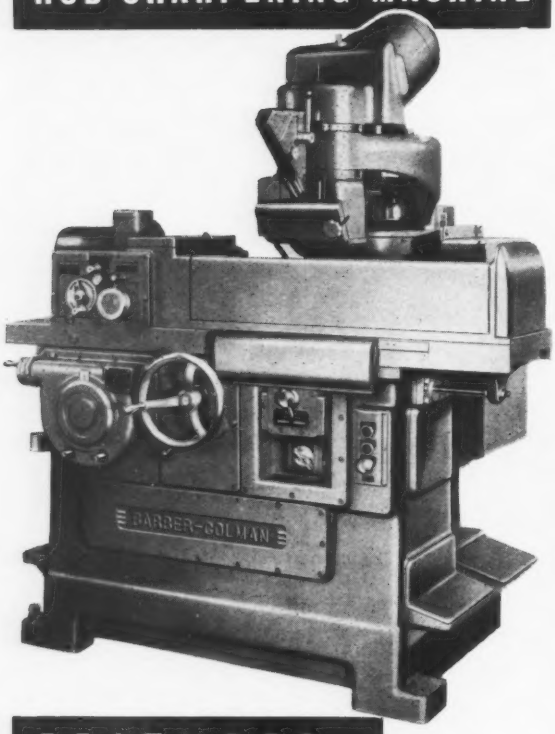

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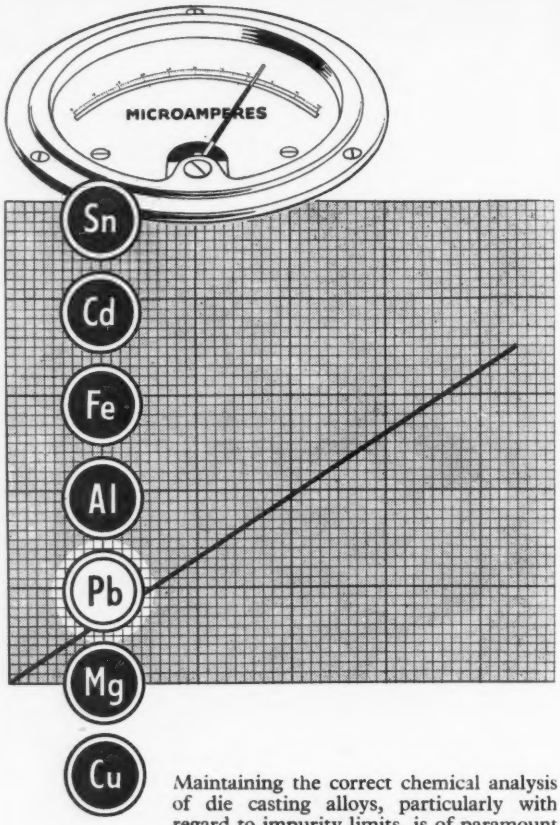

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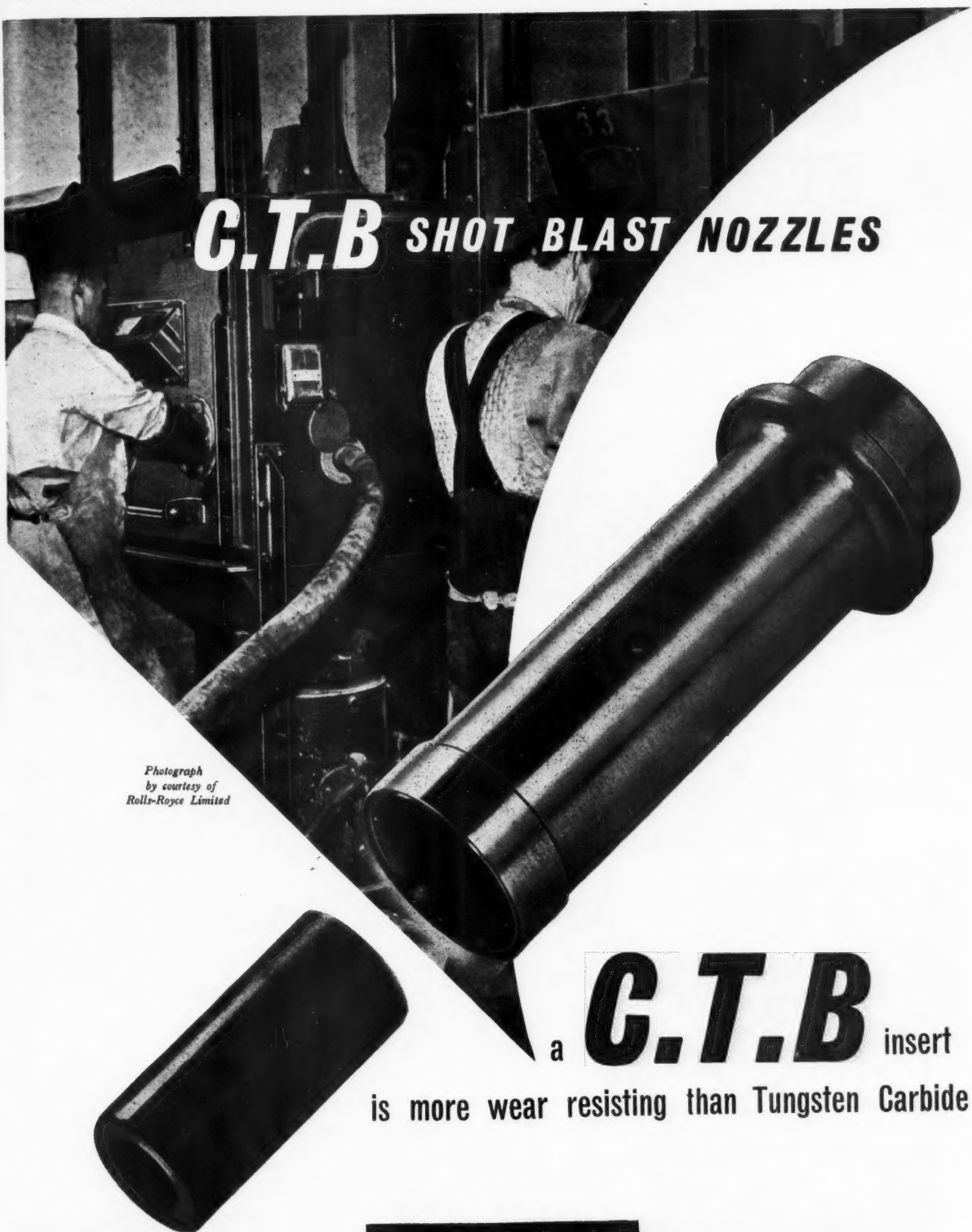

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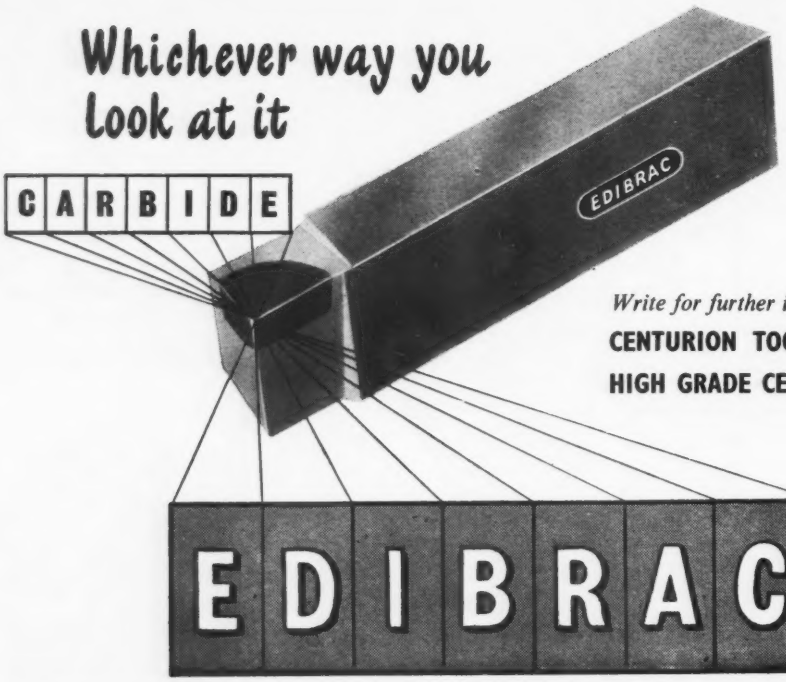

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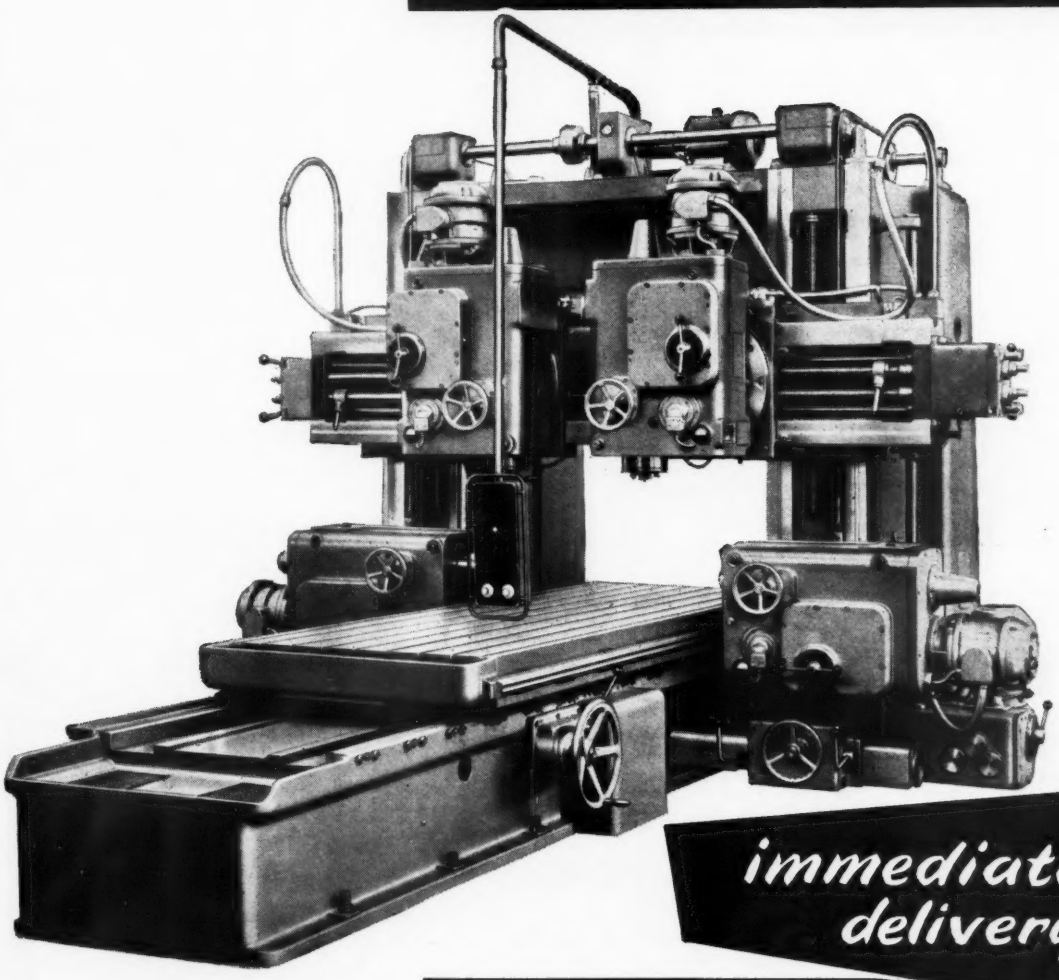

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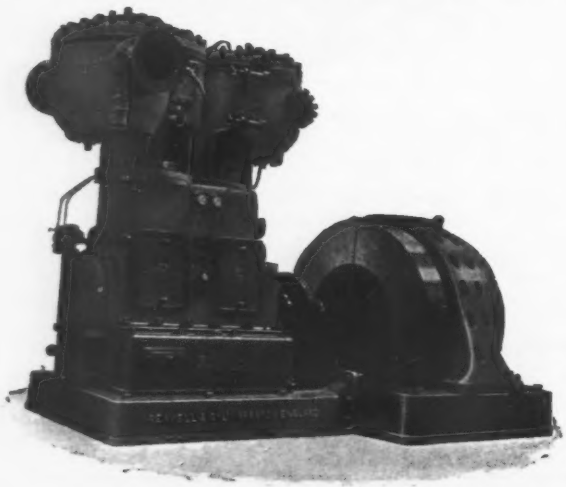

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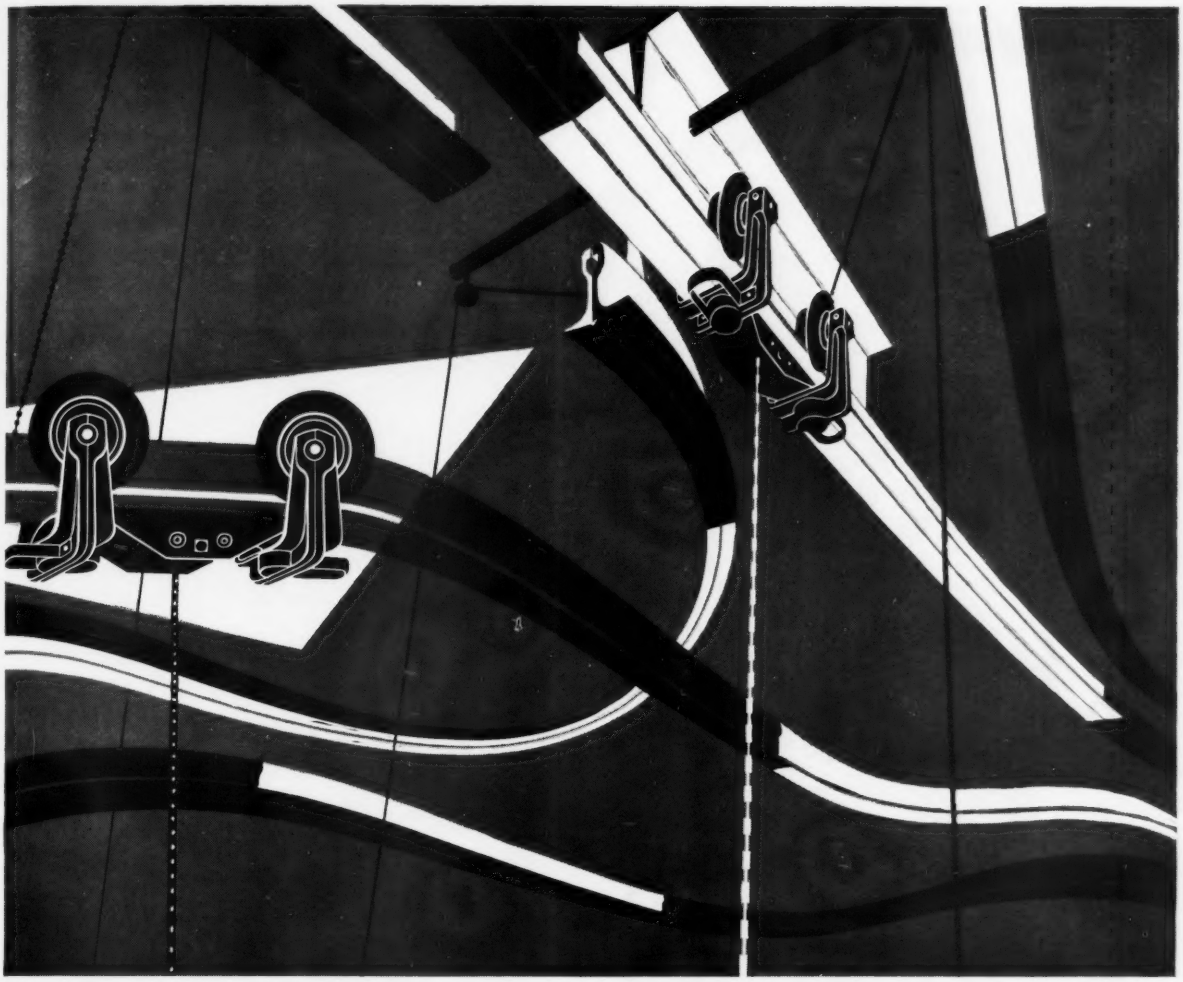

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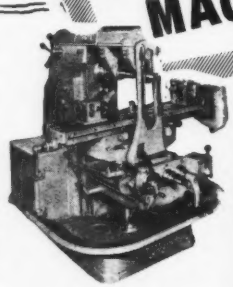

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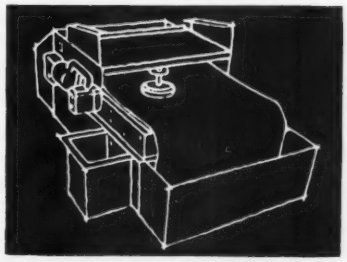

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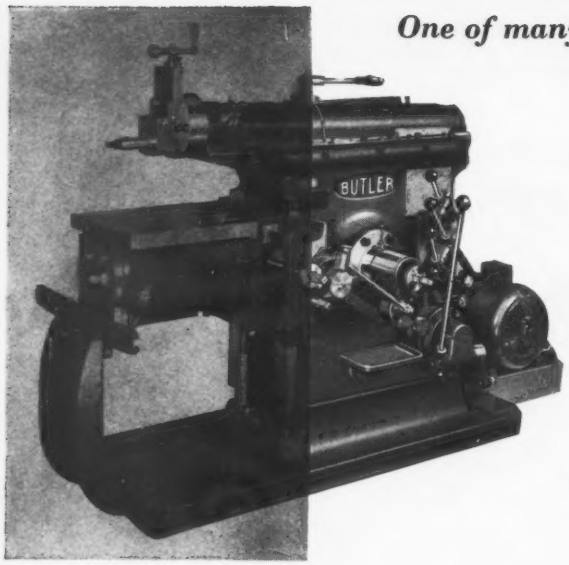

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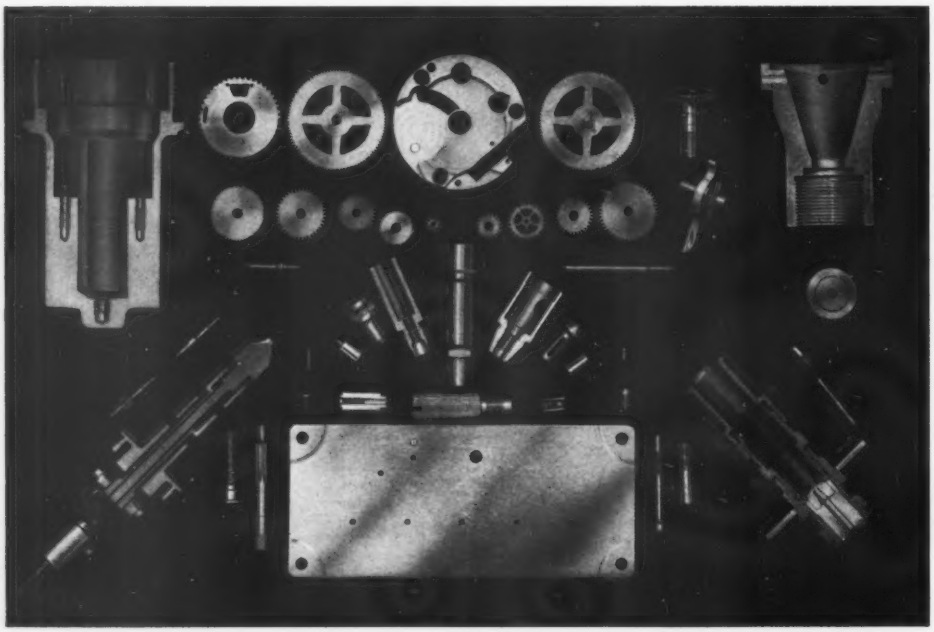

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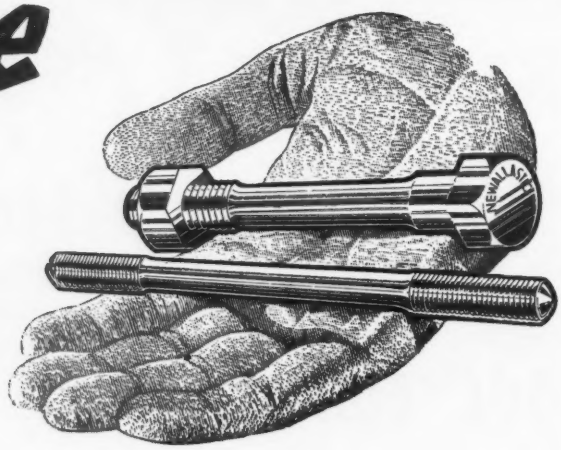

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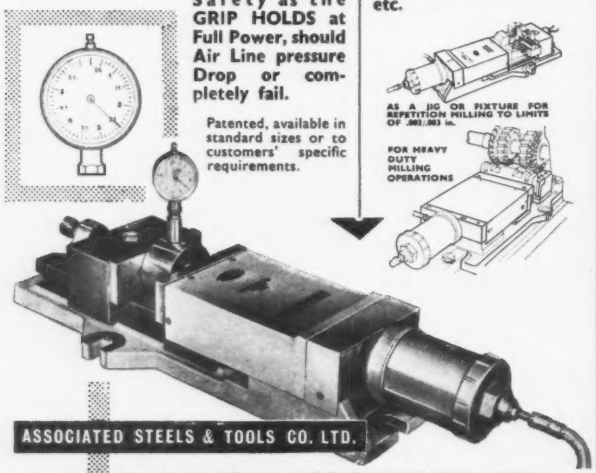

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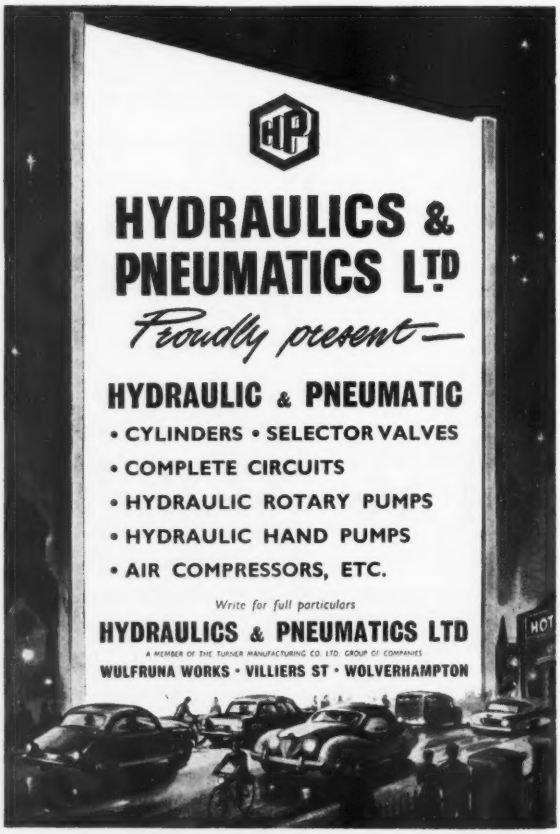
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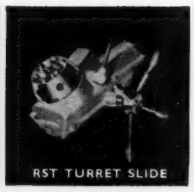
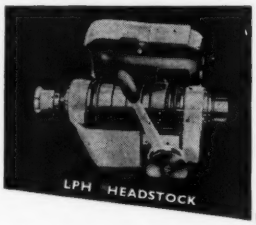

RST TURRET SLIDE

TSC TAILSTOCK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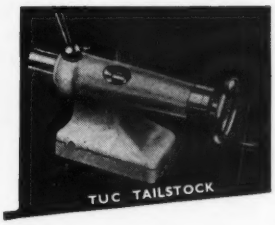
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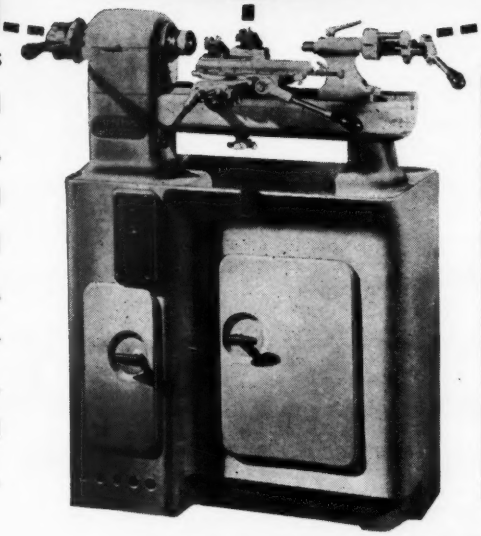

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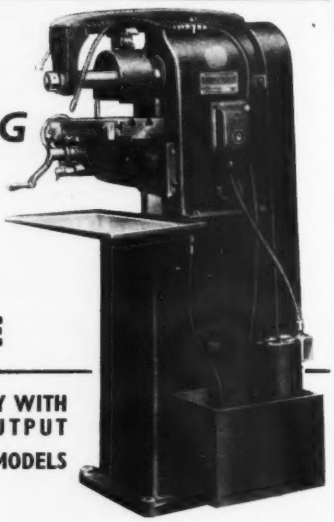

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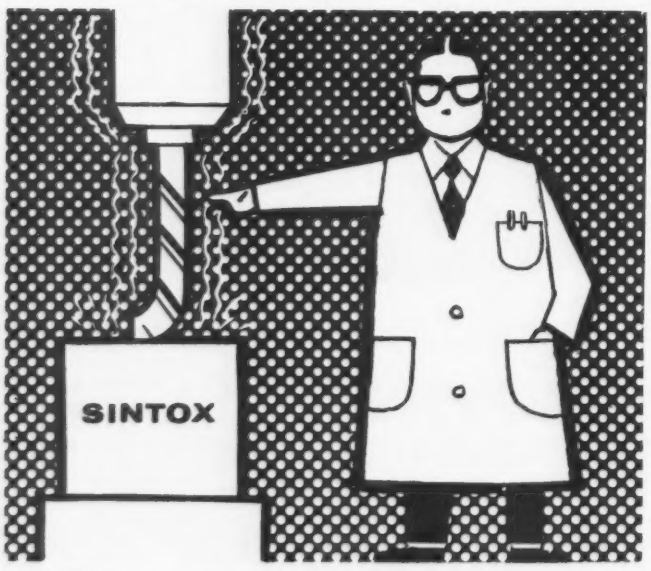

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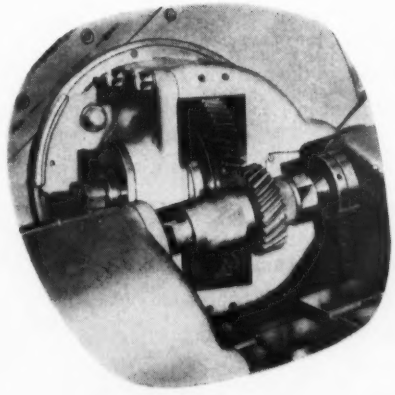
S6H · S12H

PRODUCTION GEAR SHAVING MACHINES



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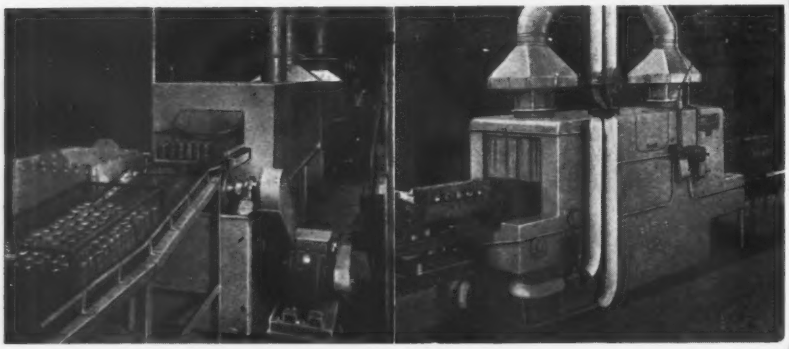
The most practical plant for Cleaning METAL PARTS

PRIOR TO ASSEMBLY, and BEFORE and AFTER REPAIRS

A 'Junior' type machine supplied to a Midlands Motor Car Works.



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A model 'A' machine washing parts of motor car engines prior to assembly.

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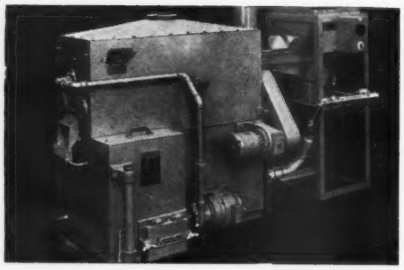

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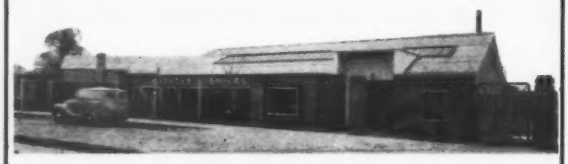

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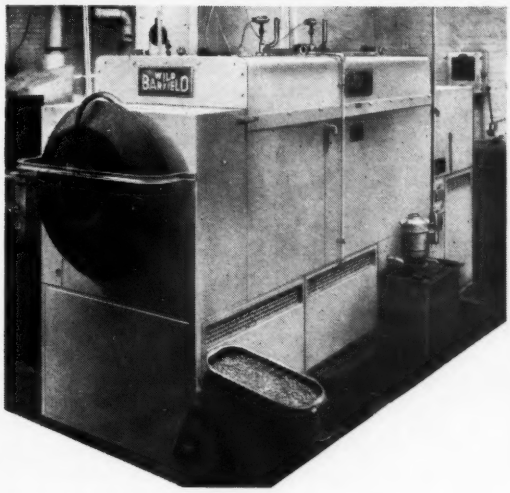

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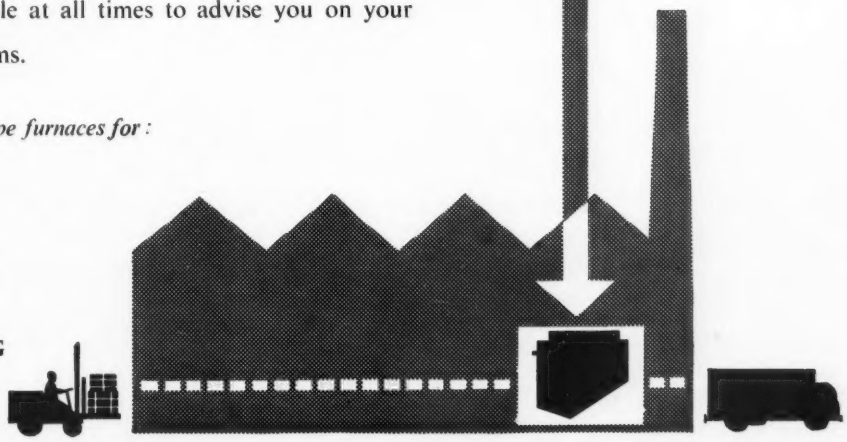

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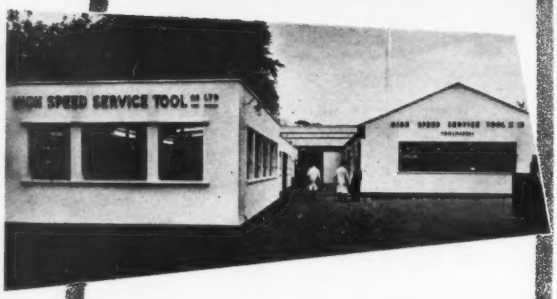

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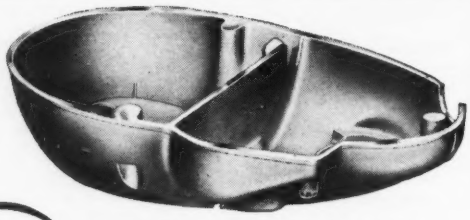

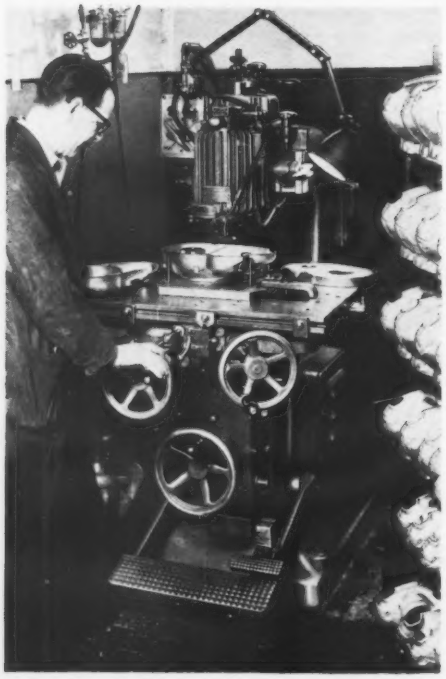

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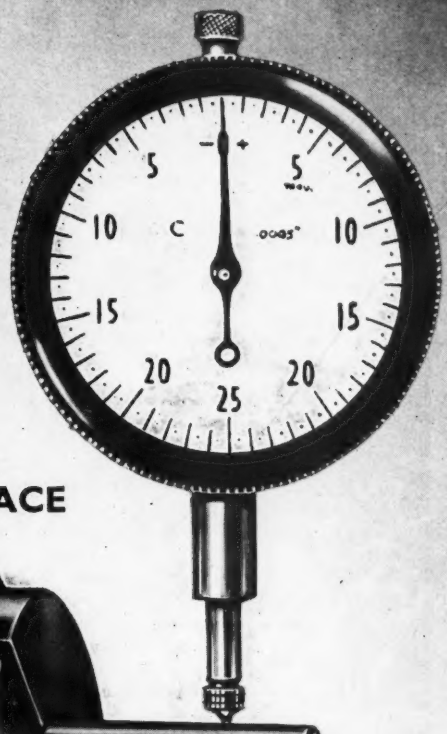

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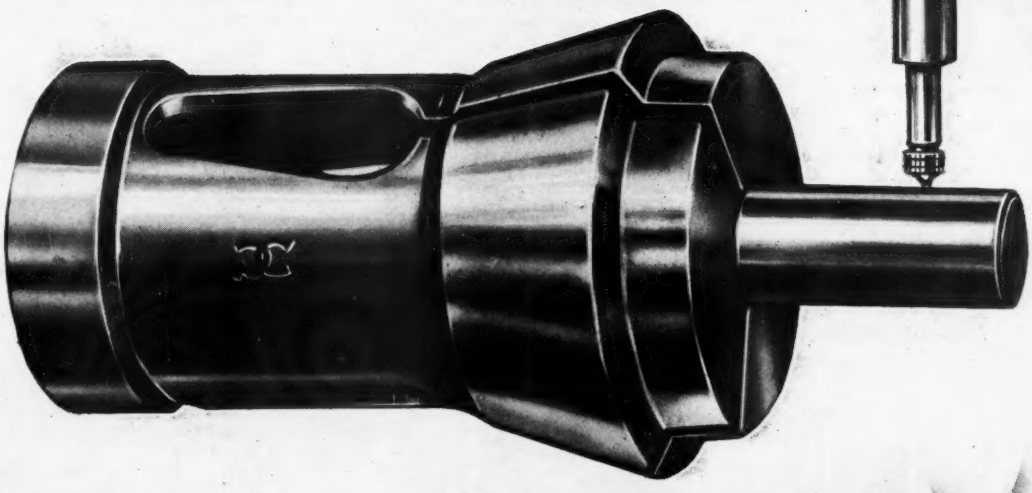

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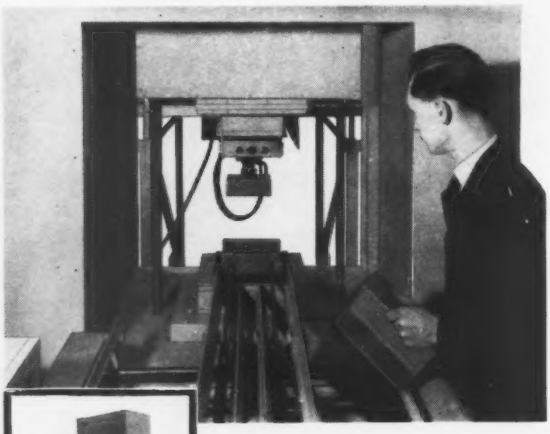

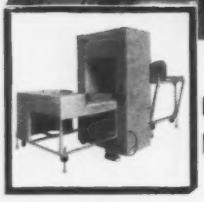

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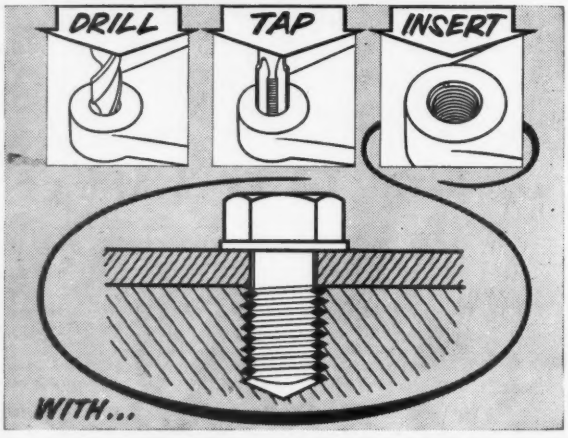

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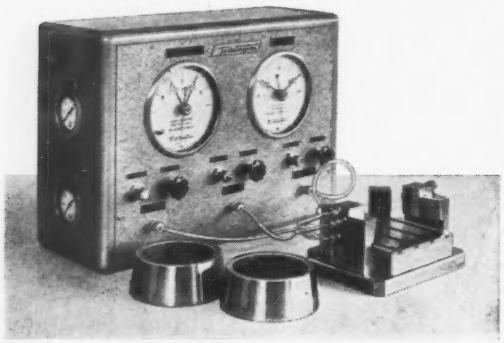

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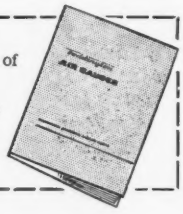

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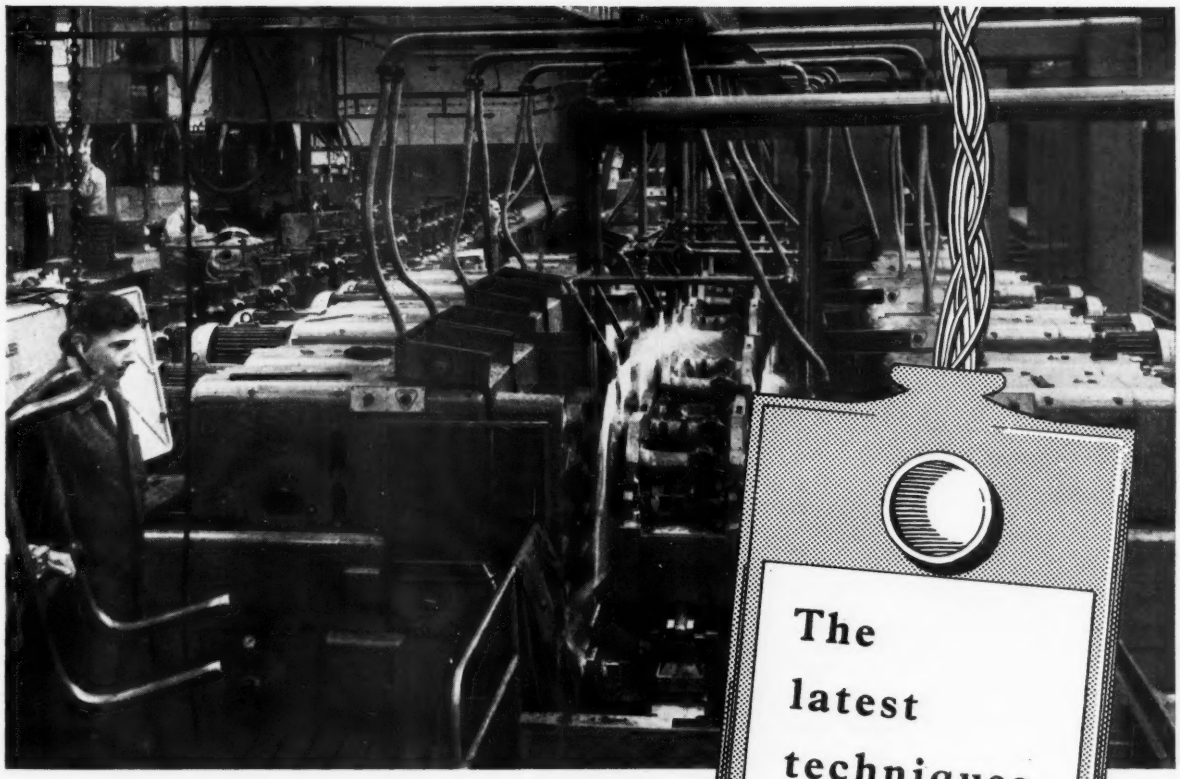

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